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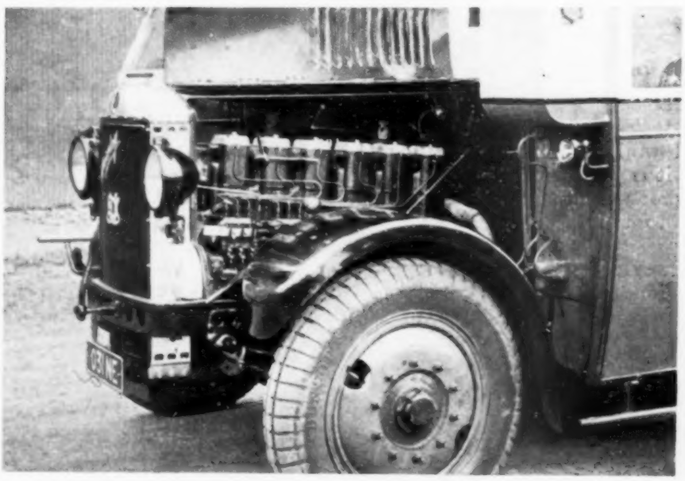
# A British Development in High-speed Oil Engines

Small high-speed engines of the Diesel type possess many striking advantages and their successful application is wide and varied.



*A 6-cylinder Gardner engine fitted to a double-saloon omnibus.*

CONSIDERABLE progress has been made during the last few years in the development of a class of oil engine which has a very useful sphere of application. It has been designed to fulfil the requirements for a wide range of duties when a petrol or paraffin motor, although having light weight and operating at high speed, is relatively costly to operate on its appropriate fuels and does not stand up particularly well to continuous hard work. Among the pioneers in this country of this special type of oil engine is the firm of Messrs. L. Gardner & Sons Limited, of Patricroft, Manchester. This company has designed a high-speed oil engine which is particularly suited for general heavy vehicle work, light locomotive work, road machinery, auxiliary and emergency ships' lighting, generating sets for radio, commercial and private house lighting, and as propelling units for small marine work. Several engines have already been adapted for remote and automatic control, a feature for which this engine is particularly suited on account of, among other advantages, easy starting, stopping, and speed regulation.

The engine is built on a system of cylinder units, which allows of any number of cylinders from one to six being assembled on the appropriate crankcase. All numbers of cylinders use standard components, and the controls are exactly similar in all cases. The standard of power of each cylinder, on a basic speed of 1,000 r.p.m., is 9.5 b.h.p, thus, engines with 1, 2, 3, 4, 5, or 6 cylinders generate 9.5, 19.0, 28.5, 38, 47.5, and 57 b.h.p., respectively ; but the engine is designed to run at any speed up to 1,400 r.p.m. It should be understood that the rated powers of these engines are such that there is sufficient margin to enable a considerable momentary overload to be taken without any appreciable drop in speed. The engines function perfectly at such a speed as 1,400 r.p.m., but they are not recommended for continuous heavy duty at these higher speeds.

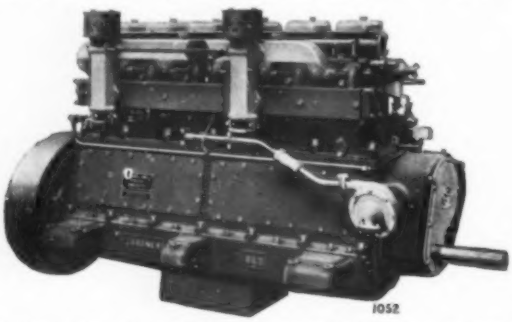
The fundamental problem associated with the design of small high-speed engines of this type lies in obtaining effective combustion in the very small time available when the engine is running at 1,000 or more revolutions per minute. Many of the leading manufacturers abroad incorporate an ante-chamber with each cylinder in order to facilitate combustion, but in the Gardner engine the open-cylinder combustion, as distinct from pre-chamber design, has several advantages. It reduces fuel consumption by as much as 12%, the piston temperature is lower, and there are no local hot spots in the combustion chamber to cause fractures. No auxiliary heating devices such as hot wire plugs or cartridges, are required to start, and the compression ratio need not be as high as that of a pre-chamber engine. That in the Gardner engine is 13—1, while a normal pre-chamber engine is anything from 15—16 to 1. This increase in compression ratio means a large increase in compression and combustion pressures which all have to be borne by the stracture of the engine. Hand starting and good combustion, when idling and running under light loads, are features only obtainable with the open-cylinder design.

The engine is of the 4-stroke-cycle type embracing the power stroke, the exhaust stroke, the aspiration stroke, and the compression stroke. Just at or before the completion of the compression stroke the fuel pump (one to each cylinder) injects a small charge of fuel through the sprayer into the combustion chamber, which at that moment is full of pure air at a high temperature due to the compression, which fuel charg is at once ignited solely by the temperature of compression, whence follows the power stroke.

In the six-cylinder Gardner engine of this type, now giving excellent service in double-saloon omnibuses, in addition to many other applications, the fuel pump assembly comprises two banks of three pumps, each pump being operated by its own cam on a short camshaft,

and carrying a lever by which it can be put into or out of action by hand. A duplex chain drives the valve camshaft, and this drives the short pump camshaft by helical gears. The fuel reaches the pumps through a combined heater and strainer, and passes thence to the atomisers, which have strainers. The pumps are of the constant-stroke type, and operate on maximum fuel-injection pressure of about 2,000 lb. per sq. in.

This type of engine is controlled by a governor, which is of the totally enclosed centrifugal kind, and which

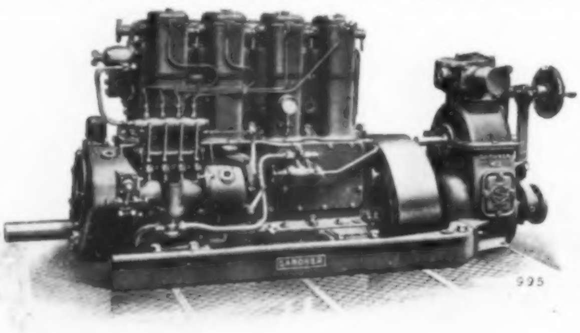



*Another view of 6-cylinder engine used for heavy vehicle work.*

automatically controls the amount of fuel injected per stroke, to suit the engine load. This engine has the ability to pull a very heavy load while running at very low revolutions and, in practice, it is possible to remain in top gear down to a very much lower speed than a petrol engine would allow. This is due to the fact that it has no carburation difficulties.

The high-speed oil engine offers many striking advantages, among which it may be metnioned that the storage of fuel oil does not entail the same difficulties as those of petrol in confined buildings. The fire risk is reduced to a minimum, as the flash point of the fuel oil is about 170° F. The engine is perfectly safe for starting by hand, as it is impossible to obtain a back-fire, because the fuel is injected into the combustion chamber too late in the stroke for this to happen. Detonation, as known in the petrol engine cannot occur in the Gardner engine for the same reason.

The consumption of lubricating oil is lower than that of a petrol engine, largely owing to the lower mean working temperature of the engine, which is such that the amount of heat to be dissipated in the cooling water is less than half

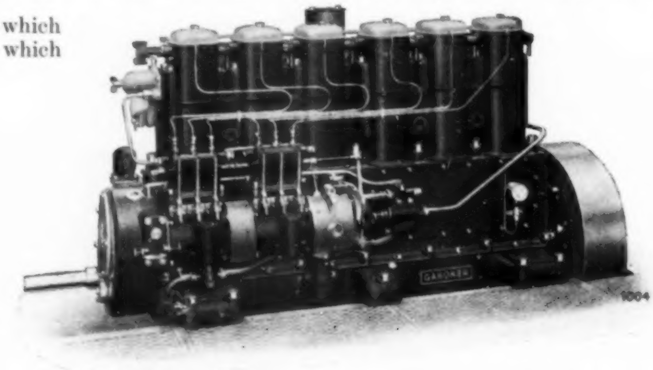



*A 4-cylinder marine unit with transmission reversing gear.*

that of an equivalent petrol engine. It is also of economical importance that the quality of the lubricating oil remains good for a longer time because it is not subjected to such high temperatures.

The advantage afforded in fuel economy cannot be overlooked; for this type of engine it is remarkably low. At normal load and speed (1,000 r.p.m.) the consumption is less than 0.41 lb. per b.h.p. hour, when using a fuel having a calorific value of about 19,200 B.th.u. per lb. The consumption at loads lower than normal is also very good. This makes the engine particularly economical in use as a traction unit, where, as is well known, it is subject to a fluctuating load which, in most cases, has a low average value.

The engine will burn all the lighter Diesel oils of specific gravity about 0.880. It will, however, burn certain heavy oils as, for example, Tarakin, which is so largely used in the East, having a specific gravity of about 0.940. For




*A 6-cylinder engine with modified crankcase for marine work.*

this fuel, however, it is necessary, for starting from cold, to use a lighter fuel, such as gas oil or paraffin; it is equally necessary to run the engine on the lighter fuel for a few minutes before stopping at the end of a day's run. After short stops of about ten minutes the engine will start on Tarakin.

In comparison with the petrol engine this oil engine uses for a given horse-power only about 50 per cent. by volume of the quantity of fuel; it can thus be safely assumed that the petrol engine burns its fuel in a less efficient manner, and some of this inefficiency is caused by incomplete combustion, which influences the character of the exhaust. Obviously the engine employing the more complete combustion must, of necessity, liberate less deleterious gases in its exhaust, both on account of its smaller total fuel consumption, and on account of the combustion being more complete. Visibility of petrol and Diesel engine exhaust gases is caused, in the case of the petrol engine, mainly be incomplete combustion; in the Diesel engine, by the fact that the exhaust temperature is low, which promotes water vapour condensation. Confirmation of this low temperature is afforded by the fact that an exhaust-valve head after several thousand miles of working can be wiped bright with a cloth.

The engine is provided with a forced-lubrication system which circulates oil through the main bearings, crankpins, and, through the tubular connecting-rod, to the gudgeon pins. In addition, the whole of the valve mechanism, the fuel-pump cams and rollers are also fed with oil under pressure from the main system. The system includes a lubrication pump, and automatic pressure-regulation valve and pressure gauge; strainers are provided, one on the suction side of the lubrication pump and one on the delivery side.

## Metallurgical Considerations.

Of the many factors that have contributed to the remarkable efficiency of this type of engine, not the least is the high standard of reliability of the materials employed in its construction. The metallurgist has co-operated with the engineer and has supplied metal and alloys to meet service conditions, while the engineer has increased his knowledge of the stresses to which various parts are subjected, and new designs have been based on superior knowledge and improved metal, to carry stresses safely. The technique of production in relation to the material involved, and the finishing and assembling of the parts, have been worked out on highly developed lines, and production, as carried on at Gardner's works at Patricroft, has reached a very high level.

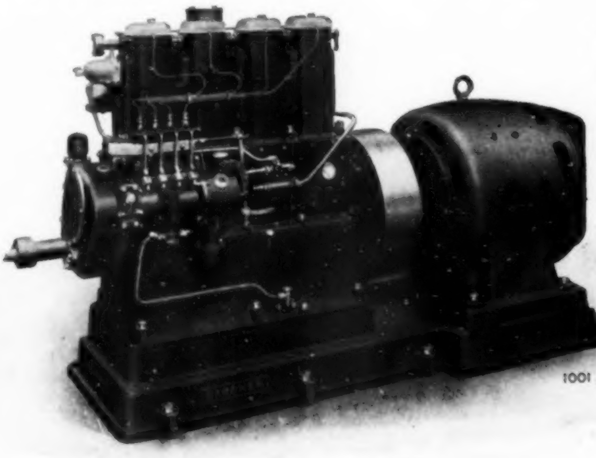
Metallurgically the material used throughout the construction of these engines is of the highest class, and of such a nature as to deal very easily with any and all stresses imposed in the course of normal running conditions. Furthermore, a rigid system of successive inspections following keen control in the manufacturing stages, ensures constancy of material and workmanship, and the finished product can be guaranteed to have certain definite characteristics within very narrow limits.

In regard to cast iron, which plays a very important part in these engine units, it will be agreed that the control and reproduction of this material in the cupola is a very indefinite operation, but conditions can be standardised and cast iron can be manufactured which, when examined from day to day, exhibits similar characteristics. The most rigid control possible will not ensure that a certain definite tensile strength per square inch will be obtained, or that a definite percentage of any of the constituents will result, but this control will give comparatively standard results.

The cast iron in the various parts for these engines is, in the first place, standardised with regard to its analysis, care being taken to keep the various constituents within very narrow limits. A system of silicon control is the principal feature, the Si content being varied according to the section of the casting and the desired hardness. The carbon content is kept as near 3.0 per cent. as possible, and the phosphorus and sulphur contents as low as possible. The general analysis of cylinder material may be taken as follows :—

| TC. | | Si. | | P. | | Mn. | | S. |
|---|---|---|---|---|---|---|---|---|
| 3.0—3.1 | .. | 1.2—1.6 | .. | 0.2 | .. | 0.6 | .. | 0.07 |

The cylinder castings, being of a very varied nature (with regard to section) are carefully controlled to ensure that a maximum hardness results in the parts that are subject to "wear." The results in this phase are very gratifying, engines in vehicles that have completed many thousands of miles (upwards of 50,000) showing very little indications of wear on the cylinder walls. The iron used in the cylinders is no exception, similar material is used in the manufacture of the cylinder heads.




*A 4-cylinder engine with dynamo.*

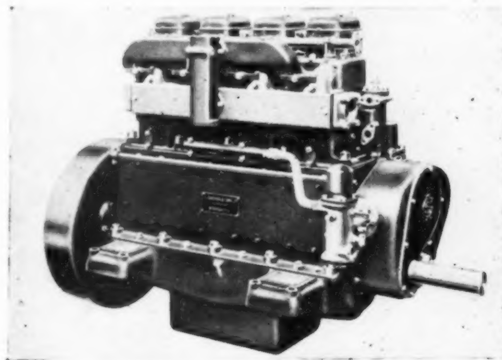
The manufacture of the flywheels is a very carefully controlled series of operations. The material used is a very high grade iron (not such as is frequently used, a heterogeneous mixture of scrap). This iron has the following analysis :—

| TC. | | Si. | | P. | | Mn. | | S. |
|---|---|---|---|---|---|---|---|---|
| 3.0 | .. | 0.9 | .. | 0.17—0.20 | .. | 0.6—0.8 | .. | 0.06—0.08 |

Some indication of the quality of cast iron is indicated by the following results obtained, from test pieces cast separately, but under similar conditions to the various castings :—

Tensile Strength in tons per sq. inch.
(Mean of numerous tests) 19.6 Max. 22.6
Transverse strength in lb. on 12 in. × 1 in. × 1 in.
3,800 Max. 4,200
(Mean of numerous tests.)
Deflection in inches. 0.15 to 0.25 at centre of span.

The moulding is very carefully controlled, and everything possible is done to ensure an even density throughout the casting, for if, after machining, a wheel weighing, say, 4 to 5 cwt., and designed to run at a maximum driving speed of 1,400 r.p.m., is more than 1 or 2 oz. out of balance,

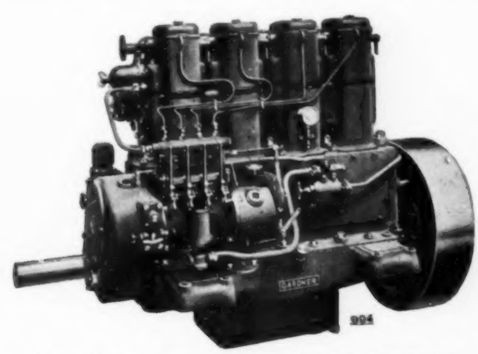


*A 4-cylinder marine engine.*

it is rejected. The drilling of the casting to approach a balanced state is not usual, as this is considered very undesirable from several points of view.

At present extensive research is being conducted into the physical state of the material of the finished castings, actual flywheels being cut up, the casting strains measured, and the physical characteristics of the material at all parts of the wheels being examined. This indicates the extreme care being taken to ensure thoroughly sound production, and is characteristic of the whole system employed in these works.

It will be obvious that the elaborate and careful control of the metal in the foundry would be futile without equally careful technical control of the sands used. All types of moulding and core sands are carefully examined and graded according to their various essential characteristics.



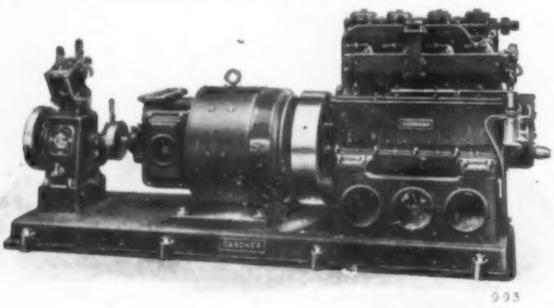

*A 4-cylinder marine engine showing fuel pump.*

In regard to the steels used, Messrs. Gardner & Sons do not manufacture their own, but the same rigid system of inspection is operative ; every batch of material is examined on its entry into the works, and if it is not to a high and rigid standard it is rejected. Such items as breech studs, connecting-rod bolts, etc., are manufactured from nickel steels having an ultimate tensile strength of 45 to 65 tons per sq. inch.

Befor leaving the material side, it should be mentioned that the organisation of this control is backed by a well-equipped laboratory which handles the chemical and physical examination of the materials, fuels, and lubricating

oils, etc., and is in a position to advise technically the various departments in the works on numerous phases and aspects of the work.

The records of the material tests (witnessed by representatives of all the authorities such as Admiralty, B.O.T., Lloyds, etc.) which have been examined by the writer, are a remarkable tribute to this organisation: strengths of materials out of the reach of many manufacturers are consistently maintained and regarded as standard.



*A 4-cylinder type with dynamo and 2-stage air-compressor.*

The company can certainly be congratulated on this most recent development of their oil-engine production, and the results obtained from these new engine units are such that they add to the prestige already earned for reliability and service. The unit system of building which has been employed reduces the number of spares necessary, even for different numbers of cylinders. The illustrations show some of the applications of these high-speed oil engines, from which it will be noted that the lower crankcase is built in two distinct types, one for marine and chassis work and one for stationary work.

It has only been possible to give a brief resumé of the general characteristics of the methods of manufacture; to go into further detail, while being exceedingly interesting, would entail the use of much more space than can be spared, but readers may be assured that this company has a tradition of which they may be justly proud. Their name is only associated with the best that can be producedii systematic research, constant experiment, practical tests, modern plant and mathods of production, tested materials, skilled work, and a progressive and constructive policy are combined to place at the service of the community products which are outstanding for reliability and performance.

## The Use of Pure Iron Electrodes for Welding Cast Iron.

DESPITE the progress in the welding of structures, particularly in regard to its use for the replacement of castings, there are still a great number of parts required daily in engineering structures which are, of necessity, made of cast iron. It is important that this should be emphasised and, indeed, it was thoroughly dealt with in a paper delivered recently to the Institution of Welding Engineers by Messrs. H. D. Lloyd and J. S. G. Primrose. Welding is, nevertheless, extremely useful as a remedy for the failures to which these castings are subject. Ordinary smith's welding with cast iron is out of the question on account of the brittleness of the iron base crystals; for the cast iron must be heated to fusion temperature before any joint of the metal can take place, and this involves many difficulties.

Considerable success has been achieved in the repairing of breakages by the use of a very soft iron, or, sometimes, a very low carbon cast-iron filling rod; another method made use of the oxy-acetelene blowpipe for melting a rod of suitable composition into the space to be filled. The great difficulty to be faced in this method, however, is the danger of a second failure, not at the actual weld, but outside the weld area; this is often caused by distortion taking place during the pre-heating process. A method which is sometimes more successful, owing to less intense heat application, is what is known as the "burning on" method, whereby the mend is effected by molten cast iron poured into a mould. The thermit process is also used to a considerable extent in this direction.

The introduction of electricity brought about a great advance in cast-iron welding methods, and its use has been greatly extended, one recent method of operation involving the use of the metallic arc, in which case the electrode itself acts as the filling rod and conveys the necessary current to melt the added metal. Practical examples have shown that a pure soft-iron filling rod is most successful in both small or extensive welds, provided that it is coated with a suitable protective flux, for by its use the whole heating effect is localised, and there is less risk of stresses in the surrounding parts of the casting. But, nevertheless, the composition of the filling rod must be suitable to the variety of cast iron being welded. Non-ferrnus metals, such as Tobin bronze and Monel metal, are used for certain very thin or very hard iron castings.

It must be admitted that welding of cast iron is not always an easy matter. Each individual case must be considered in the light of previous experience, and the best method decided upon only after all the requirements of the case have been reviewed. Experienced operators can produce excellent results, but until further steps are made in the matter of application and tests, there may be some disappointments.

## Properties of Non-Ferrous Alloys at Elevated Temperatures.

INCLUDED in the programme for the recent annual meeting of the American Society of Mechanical Engineers, was a paper contributed by Mr. C. L. Clark and Mr. A. E. White, giving the results of an investigation of the properties of certain non-ferrous alloys at elevated temperatures. The alloys considered were those of four groups:—The nickel-copper, nickel-cobalt-titanium, copper zinc, and copper-zinc-tin series, many of which find wide use at slightly elevated temperatures. The experimental work undertaken consisted of short-time tensile tests at normal and elevated temperatures, determination of lowest temperature of recrystallisation by means of hardness tests, and metallographic examination and long-time creep tests at selected temperatures. For the short-time tensile tests an electric furnace, inserted in a screw-type tensile machine, was used, the load being applied gradually up to the proportional limit, and the amount of deformation produced by each addition being determined by two Ames dials. For the long-time creep or flow tests the apparatus was of the single-lever type, a fixed load being applied. The resulting deformation was measured by two mirrors fastened to rollers, which were rotated by any change in the length of the specimen. For the determination of recrystallisation specimens of each alloy were severely cold worked, and subjected to tempering at various temperatures. Hardness readings were taken both before and after the heating operation, and the temperature at which a sharp decrease in hardness was obtained was designated as the lowest temperature of recrystallisation.

The results obtained in these tests allow certain conclusions to be drawn regarding the effect of temperature, mechanical working, and chemical composition upon the short-time tensile and creep characteristics of certain non-ferrous metals. As regards the temperature of recrystallisation the alloy series arrange themselves in the order of decreasing temperature as nickel-cobalt-titanium, nickel-copper, and copper-zinc alloys. The short-time tensile tests showed the high-nickel alloys to possess the maximum strength over the whole temperature range, Monel metal being the outstanding member of this group. Creep results showed that this group also possesses the maximum load-carrying ability at all temperatures.

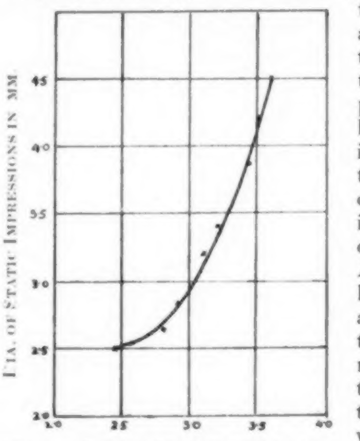
The paper incorporated complete tables and curve diagrams illustrating every phase of the investigations.

# Some Experiments on the Impact Hardness of High-Speed Steel at Elevated Temperatures

By A. R. Page.

THE behaviour of a tool steel, used for cutting metals, depends to a very large extent upon the relationship, at the temperature of cutting, between the mechanical properties of the tool steel and the material being cut. It is well known that different materials behave in different ways on heating—*i.e.*, they tend to become more plastic and weaker, while their hardness also tends to decrease.

The general practice of tool manufacturers appears to be to include some hardness test on their tools, the test varying according to the maker; but almost invariably this test is carried out at ordinary temperatures in order to ascertain whether the tool possesses the required hardness. This perhaps is for the want of something better, and, of course, any test which is adopted must be a commercial proposition. At the same time, the hardness test at ordinary temperatures seems to fall short of what is required, in order that the behaviour of the tool can be guaranteed when in operation.




DIA. OF IMPACT IMPRESSIONS IN MM.
*Fig.* I.

It has been shown by the author, in a paper presented to the Iron and Steel Institute, 1926, Vol. I., entitled "The Hardening and Tempering of High-speed Steel," that a satisfactory hardness after heat-treatment is not the sole criterion of a good performance. At the same time, the fracture also can be very misleading. It has been found quite possible to obtain a high hardness and a good fracture, even though the steel has not been properly hardened—*i.e.*, it does not possess the ideal austenitic structure. An examination of the microstructure will, of course, immediately reveal the structural state, but it is not possible to examine by means of the microscope every individual tool which is made.

The virtue of high-speed steel is that if properly treated it retains its mechanical properties—*i.e.*, its tensile strength and hardness, to a greater degree when hot. In other words, it possesses the "red-hardness property," If, however, the hardening treatment has been faulty, due to under-hardening, the steel will either consist of partially formed austenite, which, on tempering, breaks down into sorbite, or, due to over-heating, of large austenite grains surrounded by a network of eutectic material, caused by incipient fusion at the crystal boundaries. On tempering, the coarse austenite becomes coarse martensite, but the inter-crystalline network causes brittleness.

It appears somewhat problematical whether any test, short of an impact fracture test, would distinguish between over-hardened and correctly treated tools, but possibly some method of hardness testing at increasing temperatures might show some distinguishing difference between correctly- and under-hardened specimens.

As it is not convenient or satisfactory to carry out ordinary static Brinell tests on heated specimens, owing to the tempering and softening of the ball in contact with the testpieces, it was thought that some method of impact hardness testing, similar to that suggested by Edwards some years ago, might be worth while experimenting with.

An apparatus therefore was made up consisting essentially of a weight which could slide vertically between polished steel guides, this being supported by a string carried over a spindle running on ball bearings. In the underside of the falling weight was inserted a 10-mm. ball bearing, which could be easily replaced by others. The method simply consisted in placing on the anvil the heated specimen, which was rapidly transferred from a small electric furnace nearby, and allowing, by means of a quick release, the loaded ball to fall on the specimen from a predetermined height. In this way a spherical impression was produced, the size of which was measured in the usual way.

*Calibration of the Apparatus.*—In the first place it was deemed advisable to calibrate the apparatus against ordinary static Brinell numbers, and with this purpose in view a series of steel specimens (not high-speed steel) were prepared by heat-treatment, having a range of hardnesses. These were tested by the ordinary static method, using a 3,000-kilogs. load, and a 10-mm. ball, and then by the impact method. The blow delivered by the loaded ball was 64·5 ft.-lbs. From the diameters obtained, the figures of which are given in Table I., a curve was plotted, and this is shown in Fig. I.

TABLE I.

COMPARISON OF STATIC AND IMPACT BRINELL IMPRESSIONS.

| Specimen No. | Dia. of Static Impression Mm. | Dia. of Impact Impression Mms. Load 64·5 ft.-lb. |
|---|---|---|
| 1 | 2·5 | 2·45 |
| 2 | 2·55 | 2·58 |
| 3 | 2·65 | 2·80 |
| 4 | 2·84 | 2·92 |
| 5 | 3·20 | 3·10 |
| 6 | 3·40 | 3·21 |
| 7 | 3·80 | 3·40 |
| 8 | 4·20 | 3·50 |
| 9 | 4·50 | 3·60 |

*Tests on High-speed Steel.*—(*a*) A series of high-speed steel specimens was now prepared, all the pieces being hardened together at 1,250° C., for five minutes. The approximate composition of the material was:—Carbon, 0·60%, tungsten, 14·0%; chromium, 3·5%; vanadium, 0·25%. The specimens were not tempered, but were tested for hardness at ordinary temperatures to ensure uniformity.

The pieces were now heated to different temperatures and the impact hardness determined.

The results are given in Table II., together with the deduced Brinell results and also the impact-hardness figures, which are expressed as inch-pounds per square millimetre of spherical surface of the impression.

*Consideration of Results.*—It will be seen that a drop in hardness occurs as the steel is heated, a minimum being reached at 400° C. An increase then takes place with a maximum at 550° C., followed by a rapid drop after this temperature is exceeded.

It is rather interesting to compare these results with those obtained by the author, in the paper already referred to ("Journal of the Iron and Steel Institute," 1926, Vol I., Plate XLI, Fig. 36), of hardnesses determined *at ordinary temperatures* after tempering at 600° C. for ten minutes.

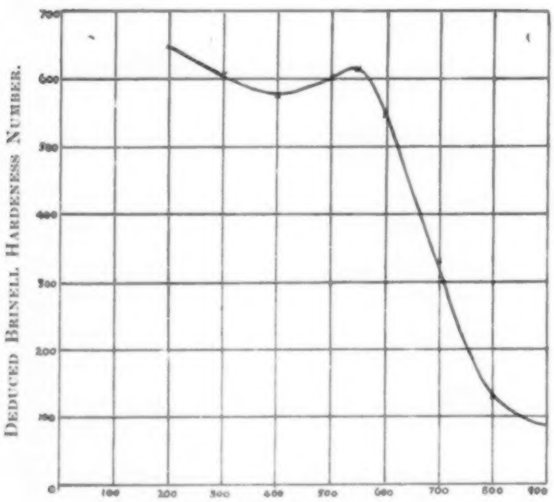
| | Previous Paper. | Present Results. |
|---|---|---|
| Maximum primary softening occurs at .................... | 400° C. with a Brinell of 585. | 400° C. with a Brinell of 576. |
| Secondary hardening at........ | 550° C. with a Brinell of 603. | 550° C. with a Brinell of 615. |

TABLE II.

IMPACT HARDNESS OF HIGH-SPEED STEEL (*a*) AT ELEVATED TEMPERATURES.

| No. | Temp. of Test ° C. | Dia. of Impact Impression Mm. | Deduced Brinell Dia. Mm. | Corresponding Brinell Figure. | Impact Hardness Figure. |
|---|---|---|---|---|---|
| 1 | 200 | 2·20 | 2·41 | 646 | 164 |
| 2 | 300 | 2·40 | 2·48 | 606 | 137 |
| 3 | 400 | 2·60 | 2·56 | 576 | 117 |
| 4 | 500 | 2·45 | 2·50 | 600 | 132·5 |
| 5 | 550 | 2·35 | 2·46 | 615 | 146 |
| 6 | 600 | 2·75 | 2·64 | 546 | 105 |
| 7 | 700 | 3·35 | 3·37 | 328 | 71 |
| 8 | 800 | 3·90 | 5·22 | 128 | 51 |
| 9 | 900 | 4·35 | 6·36 | 85 | 41 |

These figures for Impact Hardness are plotted in Fig. 2.




TEMPERATURE OF TEST ° C.
*Fig.* 2.

(*b*) A second series was now taken and deliberately underhardened—*i.e.*, they were held at 1,250° C. for only two minutes and then tempered at 600° C. for ten minutes. They were found to be uniform throughout the series, but generally considerably softer than those which had been

TABLE III.

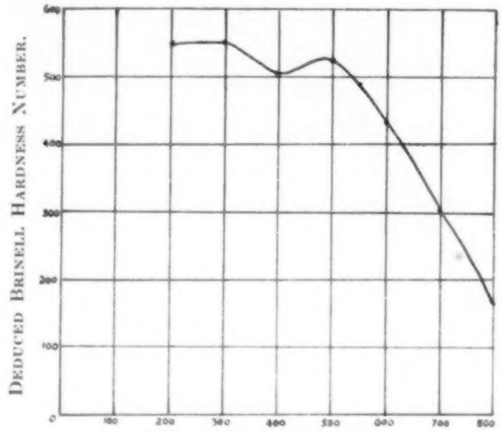
IMPACT HARDNESS OF HIGH-SPEED STEEL (*b*) AT ELEVATED TEMPERATURES.

| No. | Temp. of Test ° C. | Dia. of Impact Impression Mm. | Deduced Brinell Dia. Mm. | Corresponding Brinell Figure. | Impact Hardness Figure. |
|---|---|---|---|---|---|
| 1 | 200 | 2·70 | 2·62 | 547 | 108 |
| 2 | 300 | 2·69 | 2·61 | 551 | 109 |
| 3 | 400 | 2·85 | 2·73 | 504 | 99 |
| 4 | 500 | 2·80 | 2·68 | 524 | 102 |
| 5 | 550 | 2·89 | 2·77 | 489 | 96 |
| 6 | 600 | 3·00 | 2·95 | 430 | 89·5 |
| 7 | 700 | 3·28 | 3·51 | 300 | 74 |
| 8 | 800 | 3·80 | 4·97 | 145 | 54 |

These results are plotted in Fig. 3.

hardened only. They were then tested for impact hardness as previously, and the results are given in Table III.

(*c*) A third series was now taken and given the correct hardening treatment—*i.e.*. 1,250° for five minutes, followed by temperaing at 600° C. for ten minutes. The specimens were then tested for hardness in the same way, and the results are given in Table IV.




TEMPERATURE OF TEST ° C.
*Fig.* 3.

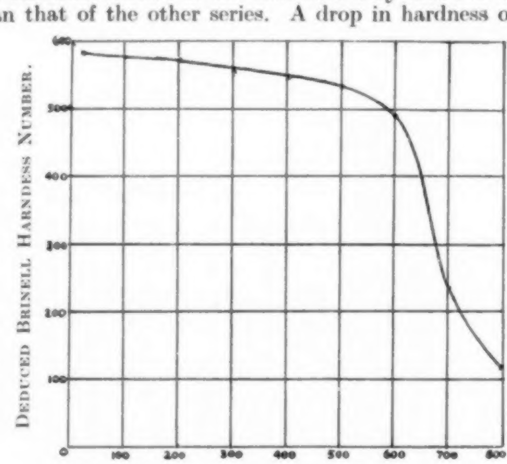
TABLE IV.

IMPACT HARDNESS OF HIGH-SPEED STEEL (*c*) AT ELEVATED TEMPERATURES.

| No. | Temp. of Test ° C. | Dia. of Impact Impression Mm. | Deduced Brinell Dia. Mm. | Corresponding Brinell Figure. | Impact Hardness Figure. |
|---|---|---|---|---|---|
| 1 | 20 | 2·54 | 2·54 | 582 | 121 |
| 2 | 200 | 2·60 | 2·56 | 573 | 116 |
| 3 | 300 | 2·68 | 2·60 | 555 | 109 |
| 4 | 400 | 2·71 | 2·62 | 547 | 108 |
| 5 | 500 | 2·78 | 2·66 | 532 | 103 |
| 6 | 600 | 2·89 | 2·77 | 489 | 96 |
| 7 | 700 | 3·45 | 3·97 | 233 | 66 |
| 8 | 800 | 4·00 | 5·47 | 118 | 48 |

These results are plotted in Fig. 4

*Consideration of Results.*—It will be noticed that, generally, the hardness results of the hardened only series is higher than that of the other series. A drop in hardness occurs




TEMPERATURE OF TEST ° C.
*Fig.* 4.

round about 400° C., and a maximum hardening at 550° C. In the under-hardened series the maximum occurs also at 400° C., but the maximum secondary hardening takes place at 500° C. With the correctly hardened series the hardness is retained with only a slight gradual drop to very nearly 600° C., when the hardness drops rapidly.

# METALLURGIA

## *The British Journal of Metals.*

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CONTENTS

METALLURGIA

THE BRITISH JOURNAL OF METALS.

# 1930 and 1931.

THE year 1930 was one of the most difficult years in the history of British industry, but the conditions, although deplorable in many respects, had perhaps some beneficial effect in that the severity of competition called for special effort for the improvement of products and methods of manufacture. This applied equally to all sections of engineering and to the non-ferrous and ferrous metal industries. The non-ferrous metal industry has not suffered acute depression over as long a period as the iron and steel industry, but it fell away considerably during last year. It is of interest that our export of non-ferrous ores and scrap fell from 88,711 tons in 1929 to 63,217 tons in 1930. The home market was also for a period in an almost stagnant condition. A survey of the engineering and shipbuilding industries explains why the iron and steel industry was so badly placed. The year closed with only one berth in four in British shipbuilding yards occupied, and two men unemployed for every one out of work the year previously. Launches during the year amounted to nearly a million and a half tons, totalling double the new tonnage booked. Against one million tons under construction in this country at the end of the year, the total building abroad was 1,500,000 tons. The British percentage of world shipbuilding which, in 1929, was over 50%, is down to about 40% at the present time. The engineering industry disposes of approximately 70% of its annual output in the home market and 30% in the export market, and exports during 1930 fell by about 14% in tonnage compared with the previous year. The tinplate industry, another large consumer of steel, suffered severely during the closing months of 1930. A steady demand was experienced for tinplates up to the end of August, but South Wales and every other country producing tinplates worked during the latter period of the year substantially below their full capacity. It is of interest to note that, during the last two years, the tinplate industry in this country has consumed nearly a million tons of steel per annum, and contrary to the statement sometimes made that the tinplate makers depend largely on foreign material, only 150,000 to 200,000 tons of that steel were imported. The chairman of Richard Thomas & Co., Ltd., expressed the opinion recently that this imported steel had actually a demoralising influence on the selling price of tinplates and that conditions in the industry would not be so difficult to-day if these imports were not coming into the country at extremely low prices. Of the total output of tinplates in South Wales it is probable that only 27½% is consumed in this country, while the remainder goes to British Colonies and foreign countries.

At the time of writing the December figures are not available, but the production of iron and steel in November was less than in October, and the number of furnaces in operation declined by four while the production of pig iron fell from 415,000 tons to 384,100 tons, and imports of pig iron amounted to 25,000 tons. Steel production at the end of 1930 amounted to little more than 50% of the output prevailing at the end of the previous year. British exports of pig iron in 1929 totalled 141,231 tons, while in 1930 the total was only 61,794 tons. Exports of ferro-alloys fell from 74,102 tons to 44,962 tons. Steel works as the year went on closed down, in some cases it is feared, permanently. At the beginning of the year the British Steel Export Association was instituted, but its efforts have been hampered by the world position, although many people are of opinion that to it is largely due the credit of influencing Canada to place more substantial orders in this country than has hitherto been the case. This was the brightest spot in the export situation, and it is probable that Canada will become an increasingly valuable customer. Australia, China, India, and Russia have not been active participants in trade for various periods of time, and for reasons which are largely, but not wholly, political, and so large a proportion of the world's consumers removed from the active list has of necessity had a disastrous effect on the supplying industries.



The demand for structural steelwork during the last year, both for buildings and bridges, was about one-third less than during 1929, when the demand was the largest for the previous 20 years, and it is becoming increasingly difficult to obtain orders even at cost price. In spite of the rebate to users of British steel the importation of structural steel is not being retarded appreciably. Cheapness is the incentive to the use of this foreign steel, but it should be borne in mind that much of this steel is of lower quality, its elastic strength being, in many cases, as low as 60% of that of British steel and, obviously, designs should be calculated accordingly.

Prospects for this year may not be bright, and it would be rash to predict a complete industrial recovery in the immediate future, but it would be equally foolish to take too gloomy a view of the situation. Sir Josiah Stamp has said that British business has no future because, while prices are falling, wages have remained stationary and taxation has been increased. But that is a business man's grouse rather than a thoughtful statement of economic truth. Present statistics do not make pleasant reading, but we like the cheery optimism of one financial expert who points out that statistics are apt to prove a two-edged weapon. Statistics always relate past history. The position studied in the figures is always last week's, last month's, or last year's. We cannot keep abreast with the times by living in the past. The world is overrun just now with statistics of the trade depression. Trade returns, unemployment figures, price indices, and a hundred and one other records remind investors almost daily of the fact. In America the glut of statistics is even greater than in this country, but all these statistics are the records of 1930 and not of 1931. They are gloomy records, but the time for gloom, as somebody has said, was the time to which the records relate—the past, not the present and future. If depression produces poor statistics it is equally true that poor statistics can breed depression; they should be looked on as lessons not as warnings, and a guide to actions in the future, not a forecast of results.

# IMPROVE SALESMANSHIP ABROAD.

THERE can be no question that this country was for long so supreme industrially that it was common practice for customers abroad to simply state their needs and material or equipment was dispatched to meet requirements. This method of securing orders is still in operation as a result of business connections that have existed between manufacturers and their clients over a long period, but it is very limited in extent. Now that many other countries have developed to such an extent that they are as highly industrialised as ourselves, competition has become very acute, and the practice of waiting for buyers to ask for materials, equipment or manufactures to be dispatched to their requirement is futile, and not in keeping with modern practice.

Business must be sought, and much depends upon the representative responsible for securing orders abroad. Indeed, it can be said with truth that as much ability is frequently required to sell a commodity as is involved in its production. The problem is discussed very forcibly by a correspondent, whose letter is published in this issue. He mentions the Republics of Brazil and Uruguay, where, in comparison with competitive countries, the amount of British structural steel imported is practically negligible. Only two instances are referred to in connection with a particular form of manufacture. Many others could be quoted, but these suffice to draw attention to the urgent need for more efficient selling organisation abroad.

Successful salesmanship is dependent upon a knowledge of the language of the people as well as the particular requirements of the country in which business is desired. This is so obvious that it seems unnecessary to refer to it, but it is precisely why the need exists, as it is the obvious which manufacturers are most apt to ignore or to omit to profit by. It is clearly necessary when attempting to do business in a foreign country to converse with its people in their own language, and yet from almost every country reports state that in too many cases our representatives do not speak or write the language of the potential buyer. Indeed, there are still export firms who correspond with him in English, quote him in English currency, send him catalogues in English with prices and quantities in English terms, and then expect to obtain business in preference to competitive nations who carry through their transactions in the buyers' language.

The fact that a representative is fully conversant with the language and is also acquainted with the needs of a prospective buyer is not sufficient in itself to effect satisfactory business. While the importance of these factors cannot be overestimated, the quality of the manufactures offered, and the technical knowledge possessed by the representative, are at least of equal importance. A representative should be fully cognisant of the processes involved in the production of the materials or manufactures for which he is responsible, in order that he can discuss them intelligently, however enlightened the probable buyer may be. The comparison between Bessemer and open-heart steel is only one of many instances that could be readily quoted where a good technical knowledge would, in many instances, make all the difference between securing and losing a substantial order.

It must be borne in mind that many countries which were formerly inhabited by a dormant people have, in view of the growing prosperity of their country, changed into an enlightened and alert people, and as many more are *now* desirous of serving their needs, it is not surprising that a more complete knowledge and understanding is *now* of vital importance to sell our merchandise abroad. Reduce production cost and increase the quality of thep roduct, if possible, but do not omit to organise intelligently the selling of the product.

# FORTHCOMING MEETINGS.

THE INSTITUTION OF MECHANICAL ENGINEERS.

Jan. 23 General meeting. "High Pressure Locomotives," by H. W. Gresley, C.B.E. (Member of Council).

ROYAL SOCIETY OF ARTS.

Jan. 26 and Feb. 2. "Some Modern Developments in Microscopy." L. C. Martin, D.Sc., A.R.C.S., D.I.C. 8 p.m.

THE INSTITUTE OF MARINE ENGINEERS.

Feb. 9. "Water-tube and/or Scotch Boilers," jointly by Messrs. Harold E. Yarrow and Summers Hunter, junr.

THE INSTITUTE OF METALS.

BIRMINGHAM SECTION.

Feb. 3. Discussion on "Refractories," to be opened by C. E. Moore and I. A. Bailey.

LONDON SECTION.

Feb. 12. H. J. T. Ellingham, Ph.D., A.R.C.S., "Electrolytic Processes in Metallurgy." (Joint meeting with the Electroplaters' and Depositors' Technical Society).

NORTH-EAST COAST SECTION.

Feb. 10. A. Wragg, B.Sc., "Stress in Metals."

SCOTTISH SECTION.

Feb. 9. D. A. Tullis, "Gas Refinement of Metals and Alloys."

SHEFFIELD SECTION.

Feb. 13. N. C. Marples, M.Sc., "The Application of High-Nickel Nickel-Copper Alloys and Pure Nickel in Industry."

SWANSEA SECTION.

Feb. 10. Julius Frith, M.Sc., "Application of Copper to the Building Trade."

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

Jan. 16. "Some Factors Influencing the Sizes of Crank-shafts for Double-acting Diesel Engines," by S. F. Dorey, M.Sc., Wh.Ex., Member.

Jan. 30. "The Whaling Factory Ship 'Vikingen,' with some Notes on Whaling," by C. F. Christensen, Member.

TEES-SIDE BRANCH.

Feb. 12. "The Manufacture and Production of Oil Engines." W. S. Burn, M.Sc., Member.

INSTITUTE OF BRITISH FOUNDRYMEN.

BIRMINGHAM BRANCH.

Feb. 12. "Symposium of Short Papers on Moulding Methods."

EAST MIDLANDS BRANCH.

Jan. 31. I.—Annual general meeting.
II.—Short Paper Competition (at Loughborough).

LANCASHIRE BRANCH.

Feb. 7. Discussion—Foundry Problems.

BURNLEY SECTION.

Feb. 10. "Mass Production from Cheap Plant." L. Wharton, Colne.

LONDON BRANCH.

Feb. 19. "Moulding a Machine Base." J. Bennett.

NEWCASTLE-ON-TYNE BRANCH.

Jan. 31. "The Sand Problem." H. F. Coggon, Halifax.

SCOTTISH BRANCH.

Jan. 17. "The Fettling Shop." Fred Gentles.
Feb. 7. "Costing." A. F. Paterson.

FALKIRK SECTION.

Feb. 14. Lecture. R. MacNab, Paisley

SHEFFIELD BRANCH.

Jan. 16. "The Vitreous Enamelling of Cast Iron." J. H. D. Bradshaw, Darlaston.

Feb. 16. General discussion on "Refractories," opened by four short papers. (Joint meeting with kindred scientific societies.)

WALES AND MONMOUTH BRANCH.

Feb. 7. Question Box and General Discussion (at Newport).

WEST RIDING OF YORKSHIRE BRANCH.

Feb. 7. "The Venting of Dry-sand Moulds." E. Flowers, Manchester.

ELECTROPLATERS' AND DEPOSITORS' TECHNICAL SOCIETY.

Feb. 12. Joint Meeting with London Section of Institute of Metals. "Electrolytic Processes in Metallurgy." H. J. T. Ellingham, Ph.D., A.R.C.S., A.M.I.Chem.E. (To be held at rooms of Motor Manufacturers and Traders Ltd.)

## Correspondence.

To the Editor, Metallurgia.

Dear Sir,—At the beginning of a New Year the thoughts of all classes of people naturally turn to the question which affects them most: their own material welfare and the welfare of those dependent on them. We wonder what the New Year will bring; whether we are going to be better off or worse off.

All our friends wish us "Good Luck." We take this to mean that they hope we might win some fabulous sum in a sweepstake, or tumble into a fortune in some other equally improbable manner. All very nice, but we know within ourselves that the best we can hope for is a decent living obtained by hard work and honest endeavour.

At the present time, however, there are over 2,000,000 people in our once prosperous little island who have not got the chance to make a living of any sort, owing to the fact that their services are not required. Quite a few of these 2,000,000 are, or were, in the steel-making business, and their services are not required because we cannot sell the material which they might produce; not because it is bad material, but because the people who might buy it don't seem to know we have it to sell.

Time was when all the world came shopping to our great English steel stores. In those days all we had to do was to take the money and promise to send the goods by the next available boat. But now all that is changed; they don't come shopping, they stay quietly at home and wait for the traveller calling with his samples and price list. And if one traveller forgets to call, or thinks it too much trouble, the one on the job, of course, gets the order.

Evidently our traveller in structural steel to the Republic of Brazil is one of those who forgets to call, or thinks it too much trouble, because, last year, out of a total of 37,433 tons, the whole of the United Kingdom sent only 586 tons. I think that traveller wants gingering up a bit.

Then, again, take the Republic of Uruguay. Although this is the smallest of the republics, last year the total import of steel of all classes was over 84,000 tons, of a total value of about £973,590 (assuming the "peso" to be valued at 4s.). The item of constructional steel was 46,000 tons, and it was mainly supplied from Belgium. The price obtained for this class of steel works out at about £9 3s. per ton. At our export price of £7 15s. per ton, and allowing 11s. per ton for freight, this allows a fair margin of profit.

We have been holding our own fairly well as regards railway material, but just recently two British-owned railways have placed orders for rails in Belgium. Together with a serious decline in sheets, this gives food for further thought. The Belgians are offering a cheaper material. It may be nasty, but it's cheaper. During the last fifteen years or so we have scrapped most of our basic Bessemer plants, as we found that the open-hearth material was much superior, although a little more expensive. The Belgians, on the other hand, retained the cheaper process, and of late years have developed it considerably. Hence their success in a country where quality doesn't seem to count so much. But it occurred to me the other day that perhaps they think they are getting quality as well. I rather think that the idea still lingers that the name Bessemer is synonymous for the very best in steel. A few weeks ago I heard a Sheffield man (a roller) argue that the Bessemer product was superior to open-hearth, and that the reason we had discarded our Bessemer plants was because the process was too expensive. Only the other day I read a story by a well-known author, in which the high qualities of the hero was likened to those of Bessemer steel. So it may be that there are prospective customers abroad who require educating as to what good steel really is.

And this is where, and why, we must send out the right kind of traveller, someone who can expound the theory of steelmaking as well as just present a price list.

Altogether, the continent of South America is buying nearly a million tons of steel of all classes annually. We should not be satisfied unless we were supplying at least half of this. Orders for half a million tons of steel would gladden the hearts of thousands of our unemployed workers, and I am sure this could become an accomplished fact. But it can only be done by organised effort and efficient salesmanship. It will be necessary to have resident agents out there in some central position, from which the whole of the continent can be regularly canvassed. Spasmodic visits or reliance on native agents is worse than useless—we must be there, on the spot, and we must make our presence known. Above all, we must make known the superiority of our products. And surely, with our organisation and resources, we can manufacture at least as cheaply as any of our competitors.

Anyway, it should be considered a national disgrace if we are going to sit down under it and admit defeat.—

Yours faithfully, Walter Lister.

Mansfield, Notts.

## Rare Metals.

Widely distributed in the earth's crust are a number of rare metals for which no commercial application has yet been found, but which have interesting qualities which may lead to their utilisation in the future. Gallium germanium, indium, and scandium are four examples of these; they are found mostly in the sulphide ores of zinc and are really just curiosities of the zinc smelter. It is possible, however, that recent progress in electrolytic zinc refining may lead to the perfection of a process for their recovery in large quantities.

Gallium, although widely occurring in zinc blend, is an exceedingly rare metal, chemically resembling aluminium and indium. It is a bluish-white, hard, tough metal, of which the chief point of interest is its remarkably low melting point (30° C.) when molten: it is not unlike mercury in appearance, and experiments have shown that it is well adapted for use in thermometers for recording temperatures above 700° C. Germanium and indium are also white metals, but have a silvery lustre; both are readily attacked by nitric acid; in all other respects they differ considerably. Germanium is brittle, analogous to tin in its physical properties and chemical behaviour; it has a melting point of 900° C. Indium, on the other hand, is a soft, ductile metal with a melting point of only 155° C and a boiling point of 1,450° C. Little is known about the properties of scandium, except that its melting point is 1,200° C. and its boiling point 2,400° C. It has frequently been asked whether it should be classed with the rare earths, for it resembles the rare earth elements in the solubility of its salts, but is in some respects analogous to the iron group.

As regards the utilisation of these metals, developments are few and suggestions many. Duralumin, "Cautal" and "Aludur" alloys containing germanium have been found to be 1 kilog. per sq. mm. stronger by its addition, while aluminium-magnesium alloys containing up to 5% germanium have been patented in Germany. No important use has been found for indium, but processes have recently been developed for its production on a commercial scale. Its wide range of temperatures leads to the belief that it might be suitable for use in high temperature thermometers. It is used in quantities ranging from 0·5 to 3·5% in bearing metal alloys. No figures are available for the production of gallium, germanium, indium, and scandium, and the small quantity produced and sold is probably the result of laboratory research rather than commercial output. The commercial future of these elements depends either upon the discovery of a large supply or on the discovery of a simple process of production, which will make them cheaper, and therefore available as substitutes for other metals. The United States Bureau of Mines has published information about these little-known elements in a circular No. 6401. Although not found in sufficient quantity to attract attention, these metals are, nevertheless, widely distributed over the earth.

# The New Alloys and——— Machine Tool Design

By Francis W. Shaw, M.I.P.E.

## Part II.—Cutting Tools.

*The reduction of cut-time with the use of modern cutting materials is only a part of the high-production problem; the reduction of non-cut-time is a problem of at least equal importance.*

HAVING examined one of the factors—improved cutting materials—that have influenced machine tools, a halt had better be called while we inquire what our title really implies, for it is not at all certain that modern machine tools owe nearly so much to the new alloys as first impressions might lead us to suppose. It is easy to ascribe improvement to the concrete and ignore the effect of the abstract—to draw, for instance, from a close-up view of steaming blue-hot chips gliding over the surface of a red-hot tool, conclusions which a larger view would reveal distorted or exaggerated.

Eliminating the distorting and exaggerating influences ought to yield a truer perspective. Let us, then, try to trace what to-day's machine tools might have been if the new cutting materials had never seen the light.

Some thirty years back, the author set himself the task of determining the ultimate saving in manufacturing cost that would be likely to accrue from certain new processes. His first step was directed towards ascertaining the ratio of machines' cutting time to the total time spent on the work. Of 80 machines, comprising lathes, planing, shaping, slotting, boring, and drilling machines, and a cylindrical grinder, all separately manned, seldom more than eight driving belts were running during many hours of observation. Closer investigation showed that of the running machines, not more than half the time was spent in cutting operations, at least half the total time being necessary to caliper diameters, measure lengths, apply cuts and feeds, and return slides for further cuts. Certainly not for more than half the total time was metal being removed. Moreover, many operations, light but time-consuming, such as tapping, screwing, reaming, and forming with broad tools, were such that high-powered tools could not materially affect the output, for the requisite accuracy and surface finish cannot be obtained at higher, or much higher, speeds or feeds.

Twenty years ago, in what was then regarded as a thoroughly well-organised works, much of the plant being semi-automatic, a rather better state of affairs existed. But since high-speed steel tools of the "pre-super" type, freely employed, would intensify the disparity between the cut-time and the total-time, whatever might have been the output compared with that of the previously mentioned works, the superiority could only have been due to the improved organisation and the better plant.

Five years ago, in a department of a highly-organised works, employing super-high-speed steel tools and stellite, the work being fully processed, of forty-odd machines, the author never observed more than seven running at a time, until the men had realised that they were under observation, and then running belts and motors did not always connote operative machines.

Generalising from the above and other similar incidents, but restricting our remarks to medium-sized and small pieces, such as are found in locomotives, gas, steam, and oil engines, electric motors, automobiles, and machine tools, we would place the average cut-time at not more than one-fifth of the total time. So it is quite evident that if the modern cutting alloys could totally annihilate the cut-time, the saving would be relatively small, and at any rate not sufficient to justify applying the term "revolutionary" to the invention or discovery of any of the alloys.

Yet, of the indirect effects of the alloys, another story may be told. They instigated many improvements, some of which, though aimed at making the machines able to cope with higher speeds and greater stresses, had the secondary effect of minimising the non-cut time. Again, the reduction of the cut-time on the simpler pieces to a half, a third, or even a fifth of the previous time, induced an ever-growing appreciation of the importance of endeavouring to minimise the non-cut-time also, to narrow the gap, so to speak, between the visible savings and the now glaringly-conspicuous losses.

Consideration of the improvements effected and anticipated shall be reserved for future instalments of this series, our present concern being with cause rather than effect, noting, however, that the initial effects, whether physical or psychological, have transmogrified themselves into new causes, motiving very drastic modifications in the means of production.

### Influence of Reductions in Cut-Time and Non-Cut-Time Compared.

First, let us suppose that the average ratio of cut-time to non-cut-time be so low as 1 : 1, though personal observation placed it nearer 1 : 5. Now, let us imagine that better cutting materials have enabled the cut-time to be reduced, but that the only modifications in the machines have been such as to enable them to cope with higher speeds and feeds. Then, for the different time units in lines 1 and 2 of Table I, the output units would increase as line 5 reveals, from which it is manifest that, however great be the improvement in the cutting materials, if the inertia persists that permitted half the total time to be expended ineffectively, the output could not possibly be doubled, for that would signify the annihilation of the cut-time—an impossibility.

TABLE I.

ILLUSTRATING INFLUENCE OF FALL OF CUT-TIME ON OUTPUT GAIN.

| | | | | | | |
|---|---|---|---|---|---|---|
| (1) Cut-time units.......... | 50 | 40 | 30 | 20 | 10 | 0 |
| (2) Non-cut-time units...... | 50 | 50 | 50 | 50 | 50 | 50 |
| (3) Total-time units ....... | 100 | 90 | 80 | 70 | 60 | 50 |
| (4) Time saved, % ........ | 0 | 10 | 20 | 30 | 40 | 50 |
| (5) Output in 100 time units | 100 | 111 | 125 | 143 | 166 | 200 |
| (6) Output increase, % ..... | 0 | 11 | 25 | 43 | 66 | 100 |

TABLE II.

ILLUSTRATING INFLUENCE OF FALL OF NON-CUT-TIME ON OUTPUT GAIN.

| | | | | | | |
|---|---|---|---|---|---|---|
| (1) Cut-time units.......... | 50 | 50 | 50 | 50 | 50 | 50 |
| (2) Non-cut-time units...... | 50 | 40 | 30 | 20 | 10 | 0 |
| (3) Total-time units ....... | 100 | 90 | 80 | 70 | 60 | 50 |
| (4) Time saved, % ........ | 0 | 10 | 20 | 30 | 40 | 50 |
| (5) Output in 100 time units | 100 | 111 | 125 | 143 | 166 | 200 |
| (6) Output increase, % ..... | 0 | 11 | 25 | 43 | 66 | 250 |

Second, let us consider what would have been the effect of speeding-up the machines, improved cutting materials being still in the offing. Visibly, then, non-cut-time reductions would have had precisely the same effect as similar cut-time reductions, as comparison of Table II with Table I will disclose.

Third, let it be assumed that non-cut-times and cut-times have equal and simultaneous drops. Then the output position would be as Table III indicates, and we see that whereas a fall in either cut-time or non-cut-time units from 50 to, say, 20—to present a practical case—results in an output increase of but 43%; like concurrent falls in both units gives an output increase of 150%—three and a half times as great. And the farther we carry the reductions the more startling becomes the output gain. Thus, if it be imaginable that both time units could be reduced to one-fifth—that is, from 50 to 10,—the output increase would be no less than six times that which a fall in either would give. So the honours are fairly even between the cutter and the machine, for further improvements in either are of comparatively little consequence unless accompanied by betterment in the other, or unless they motive improvements in the other.

TABLE III.

ILLUSTRATING INFLUENCE OF EQUAL FALLS IN CUT-TIME AND NON-CUT TIME ON OUTPUT GAIN.

| | | | | | | |
|---|---|---|---|---|---|---|
| (1) Cut-time units.......... | 50 | 40 | 30 | 20 | 10 | 0 |
| (2) Non-cut time units .... | 50 | 40 | 30 | 20 | 10 | 0 |
| (3) Total-time units ....... | 100 | 80 | 60 | 40 | 20 | 0 |
| (4) Time saved, % ........ | 0 | 20 | 40 | 60 | 80 | 100 |
| (5) Output in 100 time units | 100 | 125 | 166 | 250 | 500 | Inf. |
| (6) Output increase, % ..... | 0 | 25 | 66 | 150 | 400 | Inf. |

Inf. = infinite.

Before we pass on to a study of the many factors that enter into the non-cut-time, and control the evolution of machine tools even more than the new cutting alloys, *per se*, are doing, a little attention can profitably be given to those factors which bear directly on the cutting tools, which, as part and parcel of the machines, come within the scope of our title. How the new alloys have affected these is the question.

### Effect of New Alloys on Cutting Tools.

Even of the first high-speed steel its comparative costliness was somewhat deterrent to rapid absorption into every-day works practice. Yet, in contrast with the latest high-speed steel, it was cheap, and far cheaper than the non-ferrous stellite and tungsten carbide.

Whilst there is an inclination to debate the question of the expediency of attempts to save capital expenditure on high-speed steel by employing cheaper steels as a foundation for smaller pieces of the more expensive steel, the problem scarcely arises in the non-ferrous alloys, for these are so inherently weak that the stronger foundation is a virtual necessity.

Arguments against tipping cheap shanks are based upon the assumption that, of the steel used in tipping, fully half is wasted in forming it into a suitable tip, and in the piece left by the time the shank needs re-tipping; whereas a one-piece tool, when worn too short to afford tool-holder grip, can be re-drawn into a new tool of the next smaller standard section, and so on, again and again, the final loss thus being almost negligible. Re-drawings, it can justifiably be claimed, are far less costly than re-preparing the shank—an operation that cannot often be repeated, and a new tip is itself as costly as, or more costly than, a complete new high-speed-steel tool.

The exponents of the solid tool, however, neglect a fact which seemingly they cannot see, or which they consider a " mere detail," that more steel is lost whenever—and that is not rarely—the tool fractures or otherwise spoils in the re-heating or in the re-drawing. Our conclusion, that makers of high-speed steel, having deemed it well to sell their product as tips or incorporated in tipped tools, support the exponents of tipped tools, would be disputed by the opponents of tipping on the grounds that tipping is the more profitable, as by it steel makers are enabled to sell more steel. Further, it is convenient to neglect the fact that high-speed steel, if hardened far from the cutting edge, as it is apt to be, is likely to lose its end by shock or careless clamping, the hardened portion being more brittle than the unhardened. Forgotten, too, is that harder, hence more durable, steel can be employed in tips than in solid tools, for the tip is well supported by the shank, unbreakable and unyielding.

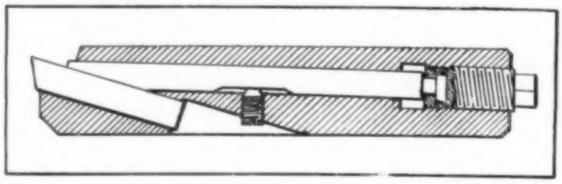

*Fig. 1.—Toolholder in which the cutter is supported at its heel and held by a wedge.*

However debatable may be the question of tipped versus solid tools, the fact of a growing inclination to support small pieces of the expensive alloys upon cheaper materials has to be faced. Besides, there is good reason to suppose that the procedure that was profitable with the older cutting materials cannot have become unprofitable with the newer—quite the reverse.

The method of clamping small pieces of steel into holders such as the " Armstrong " is too familiar to warrant description. Though for the newer high-speed steels it is as suitable as for the older steels, some care is necessary if the toolholders are employed for materials such as stellite and tungsten-carbide, on account of the inherent weakness of these materials. For these, tool-holders embodying the wedge principle of gripping in lieu of the screw, which in being tightened is apt to crack the tool, are preferable. Such a holder, designed by the author, and illustrated by Fig. 1, was very successful for holding stellite " bits " of square section. As will be seen, the bit is supported right under its heel, and the grip afforded by

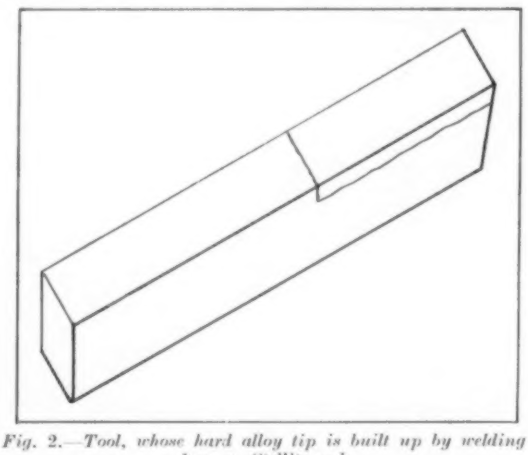

*Fig. 2.—Tool, whose hard alloy tip is built up by welding from a Stellite rod.*

the wedge, made from a hardened piece of round steel bar, whilst firm, has no tendency to localise the pressure on the bit, as would the grip from the point of a set-screw. The author is of the opinion that such holders could effectively be employed on the weaker tungsten carbide bits.

Despite the utility of tool-holders, the prevailing tendency is towards attaching the bits to shanks by brazing, welding, or fusing, though we note that stellite-tipped tools are now produced by a process of building up by the oxy-acetylene

torch or by the electric arc, a process which, incidentally, has other uses germane to our subject. Surfaces subject to rapid wear, such as the journals of shafts, sliding members, tool-rests, forging dies, shears, are now being successfully "stellited," as the process is called. Even the cutting lips of twist-drills are being built up by the process, which is claimed to be applicable also to many other types of tool. Whether by its aid we shall witness the solution of the problem of applying the higher-powered alloys to high-efficiency cutters, such as the modern cylindrical mill of large tooth pitch and large spiral angle, time will tell. Fig. 2 illustrates a stellited tool, the cutting end of which may be formed to any desired shape, the tool being known as a "silver-tip stellite tool."

The process of stelliting is analogous to that of building up by the application of other metals, the stellite being provided in $\frac{1}{4}$ in. and $\frac{5}{16}$ in. round bars. The surface to which the stellite is to be applied, whether it be steel, cast iron, malleable cast iron, or other metal, is first preheated to 680° C., and then heated with the torch or under the arc until it begins to "sweat," when the stellite rod is applied to the flame and melted on to the sweating surface. When the oxy-acetylene process is employed, the flame should be a reducing one—that is, there should be an

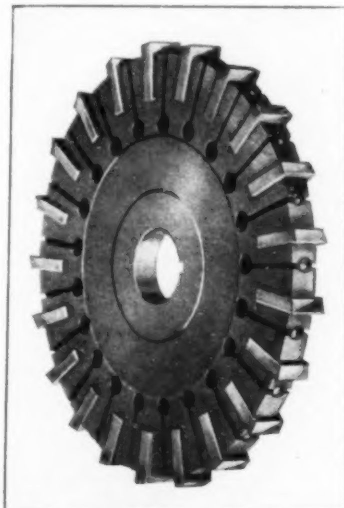

*Fig. 3.—Side and face mill with inserted and adjustable Stellite blades.*

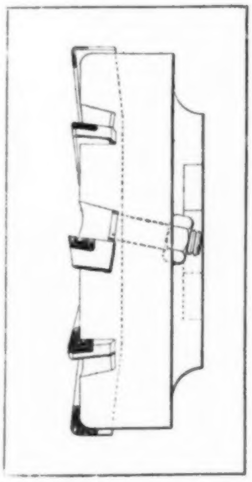

*Fig. 4.—Face or surfacing mill whose inserts are of Widia-tipped blocks secured by wedges.*

excess of acetylene. Subsequent annealing for a period of time, depending on the size of the piece, conditions the stellite surface for use, hardening not being required, in fact, being an inherent property of the alloy. The process is subject to slight variations, according to the metal in the base. Small defects, such as might be due to the occlusion of scale or surface cracks, can always be eliminated by local re-treatment. Though the price of stellite is about £1 a pound, the cost of stelliting is comparatively low, for 5 ft. of stelliting rod, weighing 1 lb., covers a 24 in. square surface with a layer $\frac{1}{8}$ in. thick. The cost of the material in most ordinary lathe-type tools would be almost inappreciable, the real cost being that of the process, and of preparing the base material.

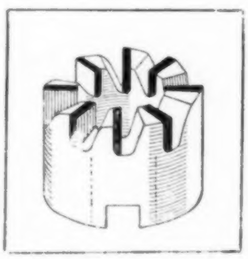

*Fig. 5.—Hollow mill whose Widia cutting elements are brazed on a high-carbon steel body.*

Of the factors of the non-cut-time, that of resetting worn tools and that due to time spent in waiting while tools are being reconditioned, make up quite a respectable portion of the whole, and are worthy of considerable study to reduce or eliminate.

Many of our existing machines are already taxed to the utmost by feeds and speeds increased to meet the heavier demands of ordinary high-speed steel. To the operator of these, the newer materials should, however, prove welcome, even though they can only increase the number of pieces obtained for each reconditioning of his tools, and possibly prevent the spoiling of work at the moment when tools are no longer capable of doing useful work.

What we are now saying applies particularly to tools which are, or carry, their own sizing device, tools among which may be classified reamers, boring cutters, slot mills, grooving mills. Consider, for instance, a cutter as that Fig. 3 depicts. The length, or the endwise position of the inserted blades, which here are pieces of stellite, controls the width of the groove milled. Obviously, as the cutter wears, it becomes narrower, and the blades must be readjusted by driving alternate blades endwise, so increasing the effective width of the cutter. Then the blades must be reground to bring the width to that required—time-consuming operations which the new non-ferrous alloys in particular do much to minimise. Milling cutters of this type, if used at their full cutting capacity, merely by virtue of the increased speed of which they are capable, will remove metal several times faster than cutters of the best high-speed steel; if used at the speeds of the same steel, their durability is many times greater. Indeed, stellite and Widia cutters have been known to run for several weeks at a single grinding against a day's run of a high-speed steel cutter.

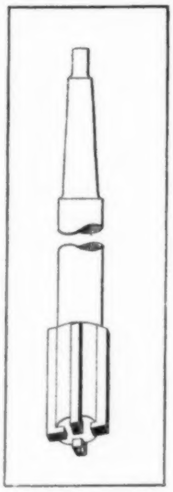

*Fig. 6.—Reamer with Widia cutting edges.*

A statement impelling a thought that, after all, the first expense is not all the expense, is that if the output be weighed against prime cost, the dearer cutter may easily prove the cheaper—if we may utter a paradox.

With Widia, the costly material is frequently employed as tips brazed on to the cheaper material, even when the whole is to form an "insert," a comparatively small element. Fig. 4 illustrates a face or surfacing mill whose inserted tipped blades are secured to the cutter body in an ingeniously simple manner. Fig. 5 shows a hollow mill in which the cheaper base material forms the body itself, Fig. 6 illustrating the same principle carried out in a reamer. Fig. 7 shows a twist-drill tipped by Widia, the body being part of the tool itself.

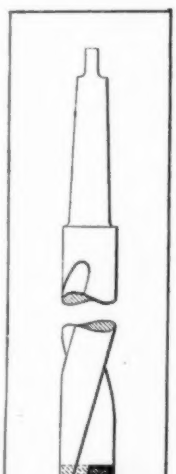

*Fig. 7.—Widia-tipped twist drill.*

## Cutting Speeds of Non-Ferrous Metals.

The non-ferrous metals to which our heading applies are stellite and tungsten-carbide, the representative of the latter being Widia.

A striking and somewhat inexplicable difference between stellite and Widia might first be noted, since it has some small influence on machine tools and their equipment. Stellite can cut efficiently; indeed is in better form for

(Continued on page 96.)

# Electric Furnaces and——— Low-Temperature Treatments.

By J. E. Oram.

*Low-temperature heat-treatments offer additional scope to the electric furnace. Low operating and maintenance costs and ease of temperature control are associated with this type of e,uipment.*

THE title of this article requires slight explanation. By "low temperature" the writer refers to temperatures up to and including 600° C. This temperature seems to be a convenient point at which to differentiate between "low" and "high," as it is at about this temperature that colour begins to appear in a furnace. In other words, a furnace appears "hot" to the eye when this temperature is surpassed.

A few years ago about the only low-temperature treatments carried out were those of tempering steels and of annealing some non-ferrous alloys. The range of tempering temperatures is, of course, fairly wide, varying from about 200° C. to 400° or 450° C., according to the nature of the work and the use to which it is to be put. Apart from these treatments, low temperatures were not required to any large extent, although the secondary hardening of high-speed steels at 600° has been carried out for some years, and is now very common owing to the increased use of this class of steel. Fresh developments in metallurgy, however, have brought to light other treatments. Nitriding, for instance, is one of the latest developments which call for low-temperature treatment. Although the use of nitrided work is not very extensive at present, time and experience will no doubt be followed by an increase in the use of this form of surface hardening. If one adds to this list the heat-treatment of the many nickel and nickel-chrome steels, such as are used to a large extent in the automobile industry, the heat-treatment of aluminium alloys, and also the heating of aluminium and aluminium alloy billets for forging, one can see that the requirements for low-temperature furnaces are great.

It is usually the case that temperature control and uniformity are even more important in low-temperature treatments than in others. In some treatments a variation of a very few degrees either way is sufficient to spoil a complete batch of work in the furnace, and it is quite natural, therefore, that one immediately looks to the electric furnace for these heat-treatments. The uniformity of temperature and the precise control available make this form of plant ideal, both from the point of view of eliminating spoilt work and from the knowledge that the product will be uniformly good.

Let us consider in detail some of the heat-treatments just mentioned. In the case of tempering, for instance, oil, lead, and salt baths and air ovens are used. Oil and salt may be used when temperatures below 300° C. are required, while salt and lead baths may be used for temperatures above this. All these types, howeve:, have a common drawback in the wastage of the tempering medium; the work, when withdrawn from the bath, holds considerable quantities of oil, salt, or lead, which has to be cleaned off, and the loss of which has to be made up from time to time, entailing considerable additional production costs. Furthermore, with salt and lead particularly, there is always the danger of introducing work which is not absolutely dry, from which cause bad accidents have occurred through the resulting explosion.

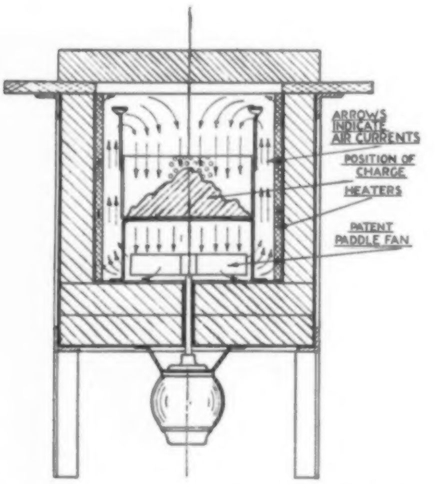


*Fig. 1.—Diagrammatic view of an oven fitted with paddle fan.*

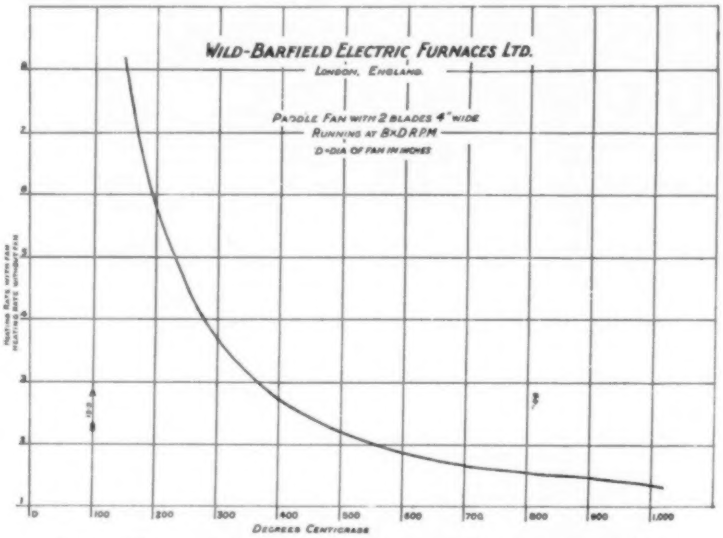


*Fig. 2.—Showing that increase in heating rate falls as temperature rises.*

Air tempering ovens, on the other hand, have none of these disadvantages, and the work does not require subsequent cleaning. One disadvantage which has hitherto been inherent in these ovens, however, was the greater time necessary to raise a charge to the required temperature. When one considers that the heat transference to the charge is almost entirely by convection at these low temperatures, it is not surprising that the rate of heating should be slower. This difficulty has been overcome by the introduction of fans into the chamber for the purpose of creating forced circulation.

A diagrammatic representation is shown in Fig. 1, of an oven fitted with a patent "paddle" fan, from which it will be seen that the fan is of the centrifugal type, designed to assist the natural convection currents. The air is drawn down the centre of the oven, where the work is situated, and is thrown outwards at the bottom, to return to the top by way of the heaters fitted at the sides. The design of the fan, which is the subject matter of patents, and the

speed of rotation, are such that, not only the maximum possible quantity of air is moved, but also in the most effective manner, and the resulting uniformity of temperature enables the variation over the whole oven to be not more than 1° C.

As mentioned, the fan, by maintaining a steady circulation of air, increases the rate of heating of the charge. Astounding though it may seem, it has been calculated

*Fig. 3.—Wild-Barfield Forced Draught Air Tempering Oven with Patent Fan.*

that the rate of heating a charge to 100° C. in an oven fitted with a paddle fan is no less than thirteen times the normal when this fan is not used, while it has been proved to be four and a half times as rapid to 250° C. It will be seen from the curve shown in Fig. 2 that the increase in heating rate falls off as the temperature increases. Even at 600° C., however, the time required to reach the temperature when the paddle fan is used, is only just over half that required without the fan. It will be realised, therefore, what a great saving in production costs can be obtained, due to the high output of a comparatively small oven, the removal of wastage of oil, lead, or salt, and to the omission of the extra operation of cleaning the work.

It might be well to state here that the paddle fan gives a high rate of heating which, in the cases under consideration, means lower operating costs. Operating costs are further reduced by the small heat losses which are obtained in electric furnaces and ovens. Fig. 3 illustrates an oven with a paddle fan installed some time ago in a large agricultural machinery works, where tests were carried out by the users. The figures obtained were as under :—

| | |
|---|---|
| Size of chamber ............ | 41 in. × 41 in. × 40 in. |
| Charge .................... | 18 cwt. 84 lb. |
| Time to heat to 215° C. ...... | 1·6 hours. |
| Soaking time allowed ........ | 0·4 ,, |
| Total time in oven........... | 2·0 ,, |
| Output rate ................ | 9 cwt. 42 lb. (per hour). |
| Maximum input ............ | 20 k.w. |
| Power to maintain 215° C. .. | 1·7 k.w. |
| Consumption over 2 hours ... | 31·8 k.w.h. |
| Pounds per k.w.h. .......... | 66 |
| Efficiency .................. | 89% |

The efficiency will be seen to be just under 90%, and this figure must be considered extremely good, for, apart from some continuous counterflow furnaces, efficiencies of 80% are as high as can be expected, and this only in an electric furnace where there are no losses due to flues.

Turning to the heat-treatment of aluminium alloys one again finds the electric furnaces of great assistance. Salt was, and is still to a certain extent, used for the heat-treatment of alloys and for heating billets for forging. The great disadvantage, particularly in the latter case, is the necessity of washing the work. When a billet is heated in a salt bath, it must be washed before being placed under the hammer, and it is found necessary to heat the billet twice, on account of the heat lost in washing. In a works where an electric furnace was installed, it was found that the complete forging could be made with one heating only, thus obviating the removal of the half-finished billet from the hammer to the furnace, and again from the furnace to the hammer. When one considers that the billets in this case weighed anything up to 5 cwt. each, one realises the enormous saving this effected in labour costs alone. In addition, " fuel " costs were reduced by the greater efficiency of the furnace and by the greater output obtainable.

In both the heating of billets and the heat-treatment of alloys of this type, temperature uniformity is essential, and fans again play an important part. Fig. 4 shows a photograph of the interior of a furnace chamber about 6 ft. long, in the roof of which are fitted two paddle fans. The heating elements are situated in the walls, roof, and floor, it being unnecessary to fit them to the door or back wall where these fans are employed. The rate of heating to about 500° C., the temperature at which the heat-treatment is carried out, is rather more than double the rate without fans, while the uniformity of temperature is greater than can be obtained otherwise.

No mention has been made of the actual method of temperature control of the electric furnace. The modern equipment comprises an automatic regulator, which, in its simplest form, is a pyrometer with an additional pointer, which can be set at will at any predetermined temperature. When the indicating pointer reaches the control pointer, by some means, either electrical or mechanical, or by a combination of the two, the current is switched off the furnace, or is reduced considerably. Owing to absorption of heat by the work and to radiation losses from the furnace itself, the temperature falls, and when it has dropped one or two degrees, the current is automatically restored to the furnace. So the process is repeated, and the temperature remains constant without human aid, enabling considerable saving to be made in production costs.

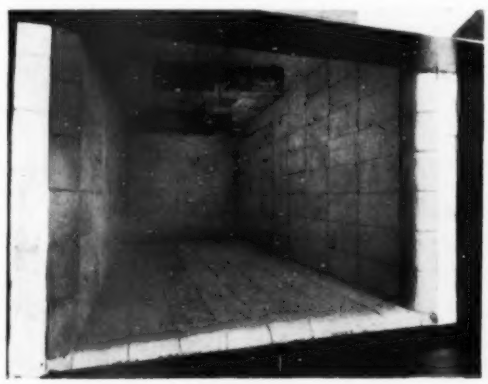

*Fig. 4.—Interior view of furnace showing patent Paddle Fan fitted in roof.*

A time switch is often fitted to the control, which enables the furnace to be switched on automatically before the works open in the morning, thus ensuring that it is ready for use when required. This switch is also used for night working without attendance. For nitriding and for carburising, which comes out of the scope of this article, where a period of soaking is required, the furnace is charged before the works close at night, and the switch is set to operate at the end of the required period.

The writer would like to make an appeal to those in

charge of heat-treatment shops to make more use of night working. Extra output can be obtained from a furnace of given size, and the increased production is obtained without any increase in labour costs. In many instances, a special cheap rate is quoted for power consumed during the "off peak" periods, usually between 5 p.m. and 8 a.m. Any furnace operating between these hours will cost less to run, yet will turn out the work which otherwise would

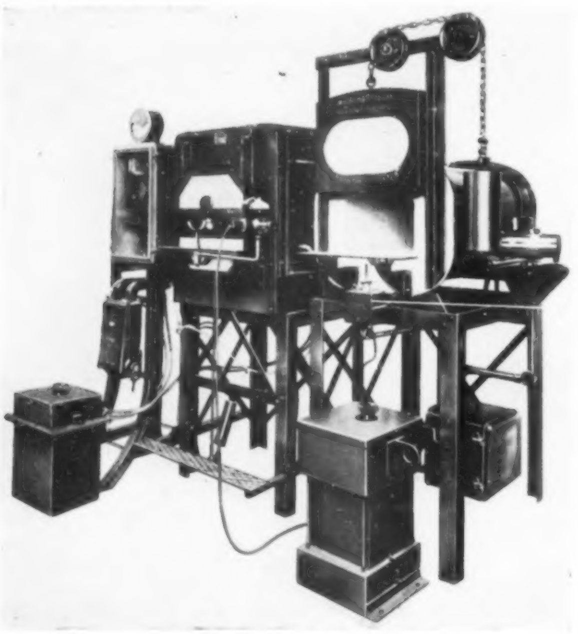

*Fig. 5.—Electric High-speed-Steel Hardening Equipment.*

have to be carried out during the day when the power costs are higher. In addition, a furnace operating continuously can be made more efficient than one intended for intermittent use only. No account has to be taken of the amount of heat absorbed by the brickwork, which is lost overnight as the furnace cools down, and thicker insulation may therefore be used, resulting in reduced heat losses. If night working was adopted generally, enormous savings would be effected annually, and investigation of the possibilities for any particular purpose is well worth while.

Amongst the low-temperature operations mentioned at the outset is that of tempering high-speed steel, and no article concerned with these treatments is complete without reference to this. Fig. 5 illustrates a twin-chambered high-speed steel equipment. The hardening chamber, being of the high-temperature type, cannot be discussed here. It is sufficient to state that it is suitable for temperatures up to 1,400° C., the disposition of the heating elements being such that there is the smallest possible variation in temperature throughout the chamber. The preheating and tempering chamber on the right is constructed so that it is suitable for preheating at 800–900° C., and for tempering at 600° C. Actually, the treatment of high-speed steel after hardening is not tempering in the ordinary sense of the word, but more of a secondary hardening operation. High-speed steel tools may reach over 500° C. when in use in a machine, and it has been found that if the steel has been tempered in the ordinary way, it soon becomes too soft, and if it has not had secondary hardening, it soon becomes soft if worked at a red heat. If, however, the tempering (as we will call it for the sake of simplicity) is carried out at higher temperatures, the tool passes a point of minimum hardness at about 500° C., and then commences to reharden. Hence the term "secondary hardening." Once this point of minimum hardness has been passed in the tempering process, the tool will remain hard, even if this temperature is reached again when in use.

It will be evident that the temperature control and uniformity play as important a part in this operation as in those already discussed, and the electric furnace is again ideal for the purpose. The unit illustrated, is suitable for a large tool-room, but in cases of high-speed steel tool production in excess of the ordinary tool-room, the unit is used solely for preheating and hardening. A second low-temperature chamber for secondary hardening is installed, and this may be a replica of the preheating chamber, or, if a very large output is required, may be of the types already illustrated with the fan in the roof or floor. These actually are decidedly superior to the smaller sizes.

To summarise the points which make electric furnaces ideal for the low-temperature heat-treatments, the advantages lie in the correct disposition of the heating elements, the introduction of the paddle fan, the ease of temperature control, and the low operating and maintenance costs associated with electric furnaces, and those interested in heat-treatment will appreciate these advantages.

## The New Alloys and Machine Tool Design

(*continued from page* 93.)

cutting when red hot; Widia is not. From which difference it might be inferred that at speeds sufficient to red-heat stellite, Widia might be its inferior. But it has been demonstrated that if Widia be used at appropriate speeds, though high, the material does not become unduly hot, the heat passing away with the cuttings, instead of being radiated by the tool. Undue heating may frequently be prevented by increasing the cutting speed, as was explained by Mr. J. R. Ward, in the discussion on his paper on "The Application of Widia Cutting Alloy," before the North-Western Section of the Junior Institution of Engineers.

The cutting speed of any machine tool is inevitably controlled not by the average conditions of its employment, but by maximum service. If, however, the maximum is rarely attained, provision need not be made for it. It would be ridiculous to allow for those repetitions of stresses for which machines are designed if they do not occur. It is sufficient to aim a little higher than the average.

It is because it has been customary for machine tools to be designed for work somewhat beyond their normal or nominal capacity, that many machines which were constructed to cope with super-high-speed steel tools are still effective on the non-ferrous alloys. But the employment of these alloys is now growing very rapidly, and machines capable of being run infrequently at higher speeds and feeds are much overworked now that the number of stress repetitions has grown, and much more of the cutting time is occupied at speeds which may be double, treble, or even more than those for which the machines were intended.

In our last instalment some indication was given of the cutting speeds of the newer alloys, more in the way of comparing them with those of the older materials than quoting maxima. Since, as we have just explained, the maximum speeds must now have a more profound effect upon construction, the machine-tool designer must needs bear them in mind. And their increase is somewhat more startling than the averages would suggest. Whilst we shall reserve for future instalments a deeper consideration of the effect of the vast speed increase, we cannot forbear alluding to the difficulty that now confronts the designer of meeting in one and the same machine the low speeds demanded by tapping, screwing, reaming, and forming operations—10 ft. to 20 ft. a minute—and the high speeds demanded by some of the yellow metals—1,000 ft.—and by aluminium—up to 4,000 ft. a minute. Allowing for work diameter differences of, say, 4 to 1 only, to meet the different speed requirements would necessitate a total gear ratio of no less than 1,600 to 1. In to-day's machines 160 to 1 is a rarity, and is obtainable only by reducing the number of speeds on the count of the expense of providing more, or, by structural complications, adding to the cost, yet reducing to reasonable height the steps between adjacent speeds. Alternatives, already studied, and embodied in some of the latest machine tools, shall be dealt with.

# Aluminium Sheet Production

By Robert J. Anderson, D.Sc.

## Part IV.—Melting Practice.

*Practice in melting metal for the production of aluminium rolling ingots is discussed. Good melting practice is essential, as sundry defects are associated with the technique of melting.*

THE fundamental principles governing aluminium-melting practice have been well established as the result of numerous scientific investigations and many years of practical experience. While the accepted rules may sometimes be violated with impunity in melting aluminium alloys for pouring ordinary castings, good melting practice is requisite and essential as a step in the production of rolling ingots. Sundry defects which may occur in aluminium sheet, notably clean slivers, dirt slivers, and blisters, are directly associated with the technique of melting. Consequently, if quality metal is to be rolled, and if the scrap losses at the inspection bench are to be held low, it is necessary that great care be exercised with the melting.

While the details of melting practice will necessarily vary somewhat, depending upon the type of furnace, the fuel used in firing, whether the batch or continuous method is employed, and other factors, two cardinal principles are to be borne in mind—viz., (1) overheating is to be avoided, and (2) cleanliness must be observed. Gassing of aluminium (and consequently blistering of sheet on annealing) is the normal concomitance of overheating. Rapidity of melting is not to be confused with overheating, as will be explained fully under the caption, "Temperature Control," later in this article. In the matter of cleanliness, it may be taken as axiomatic that whatever dirt or other solid foreign matter is charged into the furnace, when putting up the heat, will be found in the liquid metal, and consequently pass along into the rolling ingot, unless removed by some conditioning process. Overheating, *per se*, tends to cause the contamination of melts with suspended aluminium oxide. Obviously, care should be taken to ensure that floor sweepings, dross, furnace skim, chunks of bricks, sticks of wood, tramp iron, and other contaminants, should not be charged into the furnace. Melters are sometimes strangely careless when putting up heats, and dirty charging practice has been the direct cause of the loss of many a lot of metal. Failure to ensure scrupulous cleanliness of metal is promptly reflected in the appearance of dirt slivers and scales during rolling, and undue rejections on inspection of the finished sheets.

Any comprehensive discussion of aluminium-melting practice would require a volume of itself. In the present article it is the writer's object to outline the methods of melting used in rolling-mill work, and to point out the dangers of faulty technique. The discussion applies directly to melting practice as conducted in the open-flame hearth furnace, this type being mainly used in the rolling mill.* Special processes for conditioning metal—*e.g.*, degassing—before pouring into rolling ingots have been applied in practice of recent years, and these will be given some attention here.

Melting in large hearth furnaces may be done either by the batch (intermittent) or continuous methods, as described under appropriate captions below.

### Charging Practice.

As explained in a previous article† of this series, in making up melting charges for the production of aluminium and aluminium-alloy sheet, the chemical composition is controlled according to the quality of material desired or to some definite specifications. The materials used in the charge may include different proportions of primary-aluminium pig, mill scrap, customer's scrap, secondary metal, and intermediate alloys, depending upon circumstances and the composition to be rolled. These materials are suitably blended according to chemical composition.

At one plant, in putting up the heat, the weighmaster fills out a form called the "charge sheet," which gives a record of the quantities and kinds of material used. This is made in triplicate, one copy being retained by the metal department, one copy being sent to the furnace foreman, and the third copy going to the laboratory. In batch melting, after the heat has been poured, the furnace foreman fills out blanks on the form covering the number and pounds of good ingots produced, scrap ingots, pounds of furnace skim, and pounds of dross. This information is added to the other two copies of the form. In continuous melting the data collected by the furnace foreman are incorporated in the charge report when the furnace is shut down for cleaning or some other reason. The results of chemical analysis are added in due course. The work order covering each lot of sheet rolled may carry the heat number of the charge, so that complete record is available. Table I. shows a form of charge sheet.

TABLE I.

CHARGE SHEET.

Lot No. .................... Date ....................

Heat No. .................... Furnace No. ....................

| Material Used. | | Source. | Weight, Lb. |
|---|---|---|---|
| Mill scrap | Coil .......... | .......... | .......... |
| | Sheet .......... | .......... | .......... |
| .......... | | .......... | .......... |
| Primary metal | | .......... | .......... |
| .......... | | .......... | .......... |
| Secondary metal | | .......... | .......... |
| .......... | | .......... | .......... |
| Customer's scrap | | .......... | .......... |
| .......... | | .......... | .......... |
| .......... | | .......... | .......... |

| | | |
|---|---|---|
| Dross, lb. .......... | Chemical composition : | |
| Furnace skim, lb. .......... | Cu ..........% | Mn ..........% |
| Scrap ingots, lb. .......... | Fe ..........% | ..........% |
| Passed ingots, lb. .......... | Si ..........% | ..........% |

In batch operation, it is customary to do the melting at night, so that the metal is ready to pour in the morning. Hence the entire charge for the night is put up at the furnaces during the day. In continuous (or, more precisely, semi-continuous) operation, it is preferable to charge only pig metal during the day as pouring proceeds, scrap being charged at night to make up the deficiency in the day charging rate. Before charging a batch it is advisable to heat the furnace to about 700° or 750° C., but the melting

* R. J. Anderson, "Aluminium Sheet Production. Part III.—Melting Furnaces," METALLURGIA, vol. 3, No. 14, December, 1930, p. 53.

† R. J. Anderson, "Aluminium Melting Practice. Part II.—Raw Materials for Melting," METALLURGIA, vol. 3, No. 13, November, 1930, p. 4.

will proceed more rapidly if these temperatures are considerably overshot at the start of the operation.

The charging practice in batch melting may be illustrated by an example. It will be assumed that a 25,000-lb. heat is to be made for the production of 2 S sheet, and that the charge consists of about one-third, each, of primary pig, mill scrap (both baled and loose), and secondary metal. About 3,000 lb. of pigs will be charged to the hot furnace, these being scattered evenly over the hearth. The pigs should not be thrown into a high pile, and the flames should not strike directly on the metal. After the first charge has melted, 3,000 lb. to 4,000 lb. more of pig metal is put in, the pigs being shoved down into the bath of metal. Charging is continued until all the pig metal has been added. Then the baled scrap is put in, the bales being submerged in the bath, and finally the loose scrap is charged. In adding loose scrap the material should be poked down into the bath and not allowed to stand up in the path of the flames. If the pig metal is melted first and the loose scrap added last, then there is a relatively deep bath of metal in the furnace, so that the loose material can be more easily submerged. When the charging is carried out in this manner the dross losses can be held to a minimum. If the furnace is fired by oil or gas, the burners may be shut off during the charging, being again turned on as soon as the load has been added, and levelled off or submerged. Each lot should be allowed sufficient time to melt before the next charge is made. A charge of 25,000 lb. can be melted and conditioned for pouring in 10 hours or so, loads of about 3,000 lb. being added at a time every two hours.

In continuous melting, the operation is started as described above for the batch process. As pouring of ingots proceeds, cold pig metal is added to the bath. The charge rate must be adjusted so that the addition does not change the temperature of the bath too much. In a 25,000-lb. furnace about 2,000 lb. of blended pig may be added per hour. Since pouring proceeds at a more rapid rate, the deficiency is made up at night by charging a sufficient quantity of scrap. Baled scrap may be charged during pouring, but pig is preferable. In one type of furnace used for continuous melting, a preheating hearth is incorporated in the design. Cold pig is charged on this hearth, and the metal melts and runs down into the main bath.

### Batch Melting.

As the name implies, batch melting is an intermittent process—*i.e.*, a furnace is charged, the metal melted, ingots are poured until the furnace is emptied, and then a new charge is put in. It is usual practice to clean the furnace thoroughly after each heat. Thus, the hearth is well scraped, and any incrustations on the side walls at the metal line are knocked off. Batch melting is much to be preferred to continuous melting from every point of view except that of economy.

From the metallurgical point of view, better results are obtained in batch melting than with the continuous method. In the first place, greater uniformity as to chemical composition may be had by the batch method. In the second place, each batch may be properly conditioned so as to effect separation of included dross and to remove dissolved gases. Batch melting is very flexible, and may be used under any conditions. It is indicated whenever the charge is to carry much scrap or when alloys are to be rolled. During the day, when the furnace is being tapped for the pouring of rolling ingots, the temperature of the metal may be controlled accurately in batch melting. Regular and frequent cleaning of the furnace is another important feature of the batch method.

In preparing heats of alloys for rolling, it is necessary to ensure that the chemical composition is held within close limits, and that the charge is thoroughly mixed and uniform. These requirements can be met, practically, only by batch melting. In the case of alloys to be used for heat-treated sheet, the heats are usually made up from alloy pig (previously prepared and analysed) and scrap of the same composition. The 3 S alloy may be made in the furnace by charging aluminium pig and the 10 : 90 manganese-aluminium alloy, together with 3 S mill scrap. After thorough mixing, a dip sample is taken for analysis, the heat being held pending report from the laboratory. If the manganese content is not right, correction is made one way or the other, before pouring is started. Long stirring is necessary to promote uniformity of composition in a large heat. A faster method of mixing calls for first tapping out about one-tenth or so of the total quantity of metal into ladles and pouring this back into the furnace; after pouring each ladleful in, the bath is stirred and churned.

### Continuous Melting.

In continuous melting, so called, charging and pouring may be continued for several days to a week, and even for a month or longer. It is generally considered advisable to drain the furnace at least once a week for cleaning. A furnace of small capacity is not adapted to the continuous-melting process, because a large batch of metal is required to prevent undue loss of temperature when cold pig is charged. Continuous melting is carried out usually in furnaces holding at least 15,000 lb. of metal, and preferably in larger units (20,000 lb. to 30,000 lb. capacity). In the continuous method, after a bath of metal has been prepared, cold metal is charged regularly during the process of pouring. If the charge rate corresponds to the rate of withdrawal of metal for pouring, serious temperature inequalities arise. Hence, some operators prefer to charge about 1,500 lb. to 2,000 lb. of cold metal per hour during the pouring, and then fill up to the capacity of the furnace at night. This latter practice is to be preferred. Of course, if pouring is carried out continuously, then the charge rate must correspond to the rate of withdrawal.

Continuous melting is used considerably in American practice in the production of ordinary 2 S rolling ingots, but it is not regarded favourably for use with alloys. In order to maintain the chemical composition as uniform as possible, blended pig of known composition is charged regularly during the day, and mill scrap revolving from heats of the same composition as that being melted, is charged at night. With the tapping spout situated at the side near the stack end of the furnace, the pig is charged through a door opening on the opposite side near the other end. In other words, when charging during tapping, care is taken not to chill or otherwise affect the metal in the vicinity of the tap-hole. When scrap is charged at night, pouring having ceased, the practice corresponds to that described above when discussing charging practice in preparing batches.

As is obvious, the chief advantage of the continuous process is lower melting cost, since much furnace heat is not dissipated by daily cooling and cleaning. Some operators feel that continuous melting is a better production proposition than the batch method, and accordingly should be used in tonnage mills for running 2 S. Temperature control is, of course, more difficult in continuous melting, and the melts are more likely to contain suspended oxide than in the batch method. More or less aluminium oxide is introduced into a liquid bath when cold metal is charged, the quantity being proportional to the sizes of the pieces. Thus, a considerably greater quantity of oxide is introduced when light scrap is charged, as compared with 30-lb. pigs. When an aluminium pig is submerged in a bath, the metal melts and breaks through the oxide skin, leaving the oxide to become mixed with the bath. The oxide so introduced, rises, sinks, or remains *in situ*, depending upon specific conditions (viscosity of the bath and size of the oxide particles, in particular). In the bath process, the aim of conditioning after melting is to remove as much of the suspended oxide as possible. In continuous melting, it is clearly not feasible to charge almost continuously and simultaneously apply a conditioning process.

In the writer's opinion, the disadvantages of continuous melting outweigh the saving made in fuel and otherwise.

### Temperature Control.

The melting point of commercial 99+% aluminium is about 657° C., and the common alloys employed for rolling melt at lower temperatures. Broadly speaking, it is generally considered good practice to pour both ingots and castings at as low a temperature as possible. Under the usual conditions of pouring, it is necessary that aluminium be superheated about 70° C. above the melting point, so that the metal may be transferred from the furnace to the moulds without becoming too cold. Thus, when the metal is melted in a hearth furnace, and ingots are poured in conventional book moulds, the metal may be held at about 730° C. The precise temperature employed will vary, depending upon various factors. In one plant, ingots for flat-sheet production are poured at 720° C., and for coil production at 740° C. In another plant all ingots are poured at 730° C., but in some works, lower temperatures down to 700° C. are favoured.

Decreasing the pouring temperature tends to eliminate blistering on annealing, and increasing the temperature tends to eliminate dirt slivers. The lowest possible pouring temperature is indicated for bright flat sheet, because it is more liable to blister on annealing than is coil or grey plate. Blistering is, of course, associated with gassing. Increasing the pouring temperature increases the fluidity of the metal. Hence, foreign suspended matter, such as alumina, will more readily rise or sink, and less dirt slivers will be found in the sheet.

It was pointed out previously that rapidity of melting is not to be confused with overheating. In practical furnace operation, the aim in melting metal is to change it from the solid state to the liquid state as rapidly as possible. The change is accomplished when a sufficient number of calories (for a given weight of charge) have been applied, and the heat absorbed by the metal. Rapidity of melting demands hard driving of the furnace, but the metal cannot be overheated until after it has been liquified. It is doubtful that aluminium may become seriously gassed by exposure to a high temperature in the solid state. Even if it were gassed, the gas may be removed subsequently by a refining process. In melting, temperature control is important after the metal has been liquified, and if the furnace atmosphere is not highly oxidising, it is very doubtful that aluminium is damaged by rapid melting. Some metallurgists claim that aluminium should be melted slowly, meaning that hard driving is not to be tolerated, and that the temperature of the furnace should not greatly exceed that of the metal. Such melting is out of the question in commercial work. As a practical matter, in liquifying aluminium, a hearth furnace may be driven so fast that the roof bricks soften and drip without damage to the metal. Ordinarily, the temperature of the liquid metal should not be allowed to exceed 760° C.

In batch melting, where speed is essential, the furnace may be driven as rapidly as desired until the charge has liquified, when the fuel supply is cut off or reduced. Any considerable absorption of heat by the bath from the walls and roof, may be counteracted by charging cold pig.

After the entire charge has been melted, pyrometric control should be applied. In ingot-pouring practice, automatic control of the temperature is advantageous. Thus, in large hearth furnaces one burner may be equipped with control valves. When the metal is at the proper temperature and ready to pour, this burner may be cut in, and sufficient fuel fed automatically by the controlling mechanism to compensate for the radiation losses from the furnace and maintain the metal at the proper temperature. In coal- or coke-fired furnaces, where temperature control is difficult, the fire may be banked on the grate after melting is completed, and the metal then held at the required temperature for pouring by means of an automatically controlled gas burner.

Pyrometric equipment for the measurement and control of metal temperatures is standard, and need not be described here. For taking temperatures of ladles prior to pouring and in other intermittent use in aluminium, base-metal couples may be employed without protective sheaths. However, when thermocouples are used for the continuous measurement of temperatures of liquid aluminium, suitable protection must be provided to prevent alloying of the couple elements with the metal. Long experience has shown that ordinary grey cast iron is the most satisfactory material available for use as protective tubes in aluminium practice. For semi-permanent installation in a hearth furnace, a length of cast-iron tube, about 3 ft. long, may be welded to a heat-resisting steel tube, the cast iron only being exposed to the metal. If a continuous recorder is used for registering the temperature during pouring, permanent record will be available.

Various wash coatings are used to increase the life of cast-iron protective tubes. A usual wash consists of hydrated lime and water, to which a little sodium silicate is added. Brook, Simcox, and Wilson[12] recommend a wash made of equal parts of French chalk and graphite mixed with 10% sodium-silicate solution to the consistency of thin cream.

### Conditioning of Metal.

Aside from chemical composition, the quality of metal obtained on melting aluminium and its alloys depends in large part on temperature control, technique of furnacing, and the application of refining processes—*i.e.*, methods for degassing and removing foreign suspended matter. The fuel used in firing is also a factor. While there is considerable divergence of opinion as to the value of fluxing aluminium with metallic salts—*e.g.*, zinc chloride—most metallurgists agree that treatment with an inert or an

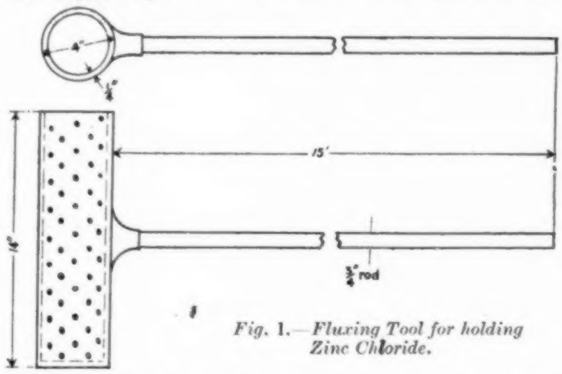


*Fig. 1.—Fluxing Tool for holding Zinc Chloride.*

active gas is good practice. After the charge has been melted, the bath should be put into condition so that it is ready for pouring. The conditioning then entails the adjustment of temperature to the desired degree, fluxing, and degassing. In batch operation, where the charge is melted at night, the furnace crew will put the metal into suitable condition, so that it is ready for pouring in the morning. Fluxing or degassing may be done at periodic intervals during the day, if circumstances require. Whenever a bath is considerably agitated by stirring, fluxing, gas treatment, or otherwise, good practice calls for allowing it to stand quietly for a short time, so that suspended matter may have opportunity to rise or sink.

Methods of conditioning metal prior to pouring, vary considerably in different mills. In batch melting, at one plant, it is practice to flux with zinc chloride. The method is as follows: When the entire charge has been melted, and the metal reaches about 720° C., the burners are shut off. The temperature may rise appreciably, due to absorption of heat from the walls and roof, but it is prevented from rising over 760° C. by charging cold pig, if necessary. Gas absorption may be appreciable at higher temperatures. In fluxing, the metal is treated with anhydrous zinc chloride, held in a special tool. The quantity used is about 1 oz. per 300 lb. to 400 lb. of metal. Fig. 1 shows the type of tool used. This consists of a grey cast-iron cylinder, closed at one end, and perforated over half the surface area with small holes. The cylinder is welded to a suitable handle. The salt is put into the tool, and this is then submerged in the metal, being worked back and forth

across the hearth. Volatilisation of the salt causes upward currents in the bath, so that suspended matter is brought to the surface. The operation requires about five minutes. After this, the bath is allowed to stand quietly for 20 to

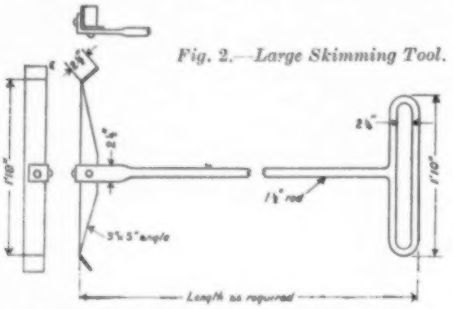


*Fig. 2.—Large Skimming Tool.*

30 mins., when the dross is taken off with a suitable skimming tool. Fig. 2 shows a form of skimming tool used in large hearth furnaces. During the course of pouring —*e.g.*, at noon—the bath may be again fluxed.

In another plant, no flux is used in the furnace, but the melt is skimmed two or three times during the course of tapping—*i.e.*, every three to five hours.

Various metallic salts other than zinc chloride are used in practice for fluxing aluminium melts, including ammonium chloride, aluminium chloride, magnesium chloride, and sodium silicofluoride. The dross taken off from melts is normally to be re-worked for metal. Dry, lean dross removed from the bath on fluxing after melting, should be kept separate from rich skimmings taken either from the furnace or from pouring ladles.

Aluminium may be fluxed in the crucible or pouring ladle, after removal from the furnace. At one plant, zinc chloride is stirred into the metal with a small fluxing spoon, such as is shown in Fig. 3. The metal is then carefully skimmed before pouring. Where tapping-type hearth furnaces are used, the tap-hole may be plugged with a dough-asbestos ball. On pulling out the plug, the dough ball is usually carried into the receiving vessel, and must be fished out. Fluxing or degassing in the pouring ladle appears to be advisable when metal is melted in tapping-type furnaces. Every time the tap-hole is plugged with a fresh dough ball, the metal is locally gassed more or less, due to the drying-out of the damp ball. At one plant, aluminium chloride is used for fluxing in the pouring ladle; the salt is contained in an aluminium capsule, which is submerged in the metal with a special perforated pipe-tool.

Methods for degassing aluminium melts by bubbling an inert (nitrogen) or chemically active (chlorine or boron chloride) gas through the metal, have been developed of recent years. Such methods are also efficacious in pro-

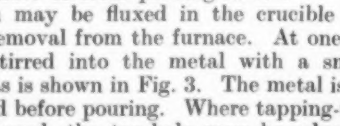


*Fig. 3.—Fluxing Spoon.*

moting the removal of suspended matter. Both chlorine and nitrogen have been used to advantage in the writer's practice for conditioning melts of aluminium and alloys prior to pouring rolling ingots. Gas treatment may be substituted for fluxing. Thus, after melting, the bath may be treated with chlorine. Fig. 4 shows a form of special tool used for degassing. This consists of a grey cast-iron cylinder, closed at both ends, and perforated with small holes. The cylinder is attached to a supporting framework and pipe handle. Connection is made to the gas source (nitrogen or chlorine contained under pressure in a steel cylinder) by means of rubber hose. Suitable reducing valves are interposed for regulation of the pressure. When chlorine is used, it is advisable to provide a connection in the rubber hose, close to the steel cylinder, to a compressed air line, so that at the end of the degassing operation the chlorine may be blown from the tool while it is in the furnace, thereby avoiding contamination of the air in the melting room. In the operation of degassing, the tool is shoved into the furnace, gas turned on, and then the tool is plunged beneath the surface. With gentle bubbling, treatment for 8 to 12 mins. is ordinarily long enough, the tool being worked back and forth across the hearth. After degassing, the melt may be allowed to stand quietly for 10 to 20 mins., and is then skimmed. Metal may also be degassed in the crucible before pouring. Coke firing is favoured for aluminium by some operators, because the tendency toward gassing is apparently less than with gas or oil firing.

### Melting Losses.

The loss in melting aluminium, due to oxidation, varies considerably, depending upon the nature of the charge, the furnace atmosphere, temperature, and other factors. The dross loss is increased with increasing quantities of light unbaled scrap in the charge, with oxidizing atmospheres, and with increase in temperature attained by the bath. With good operation, the total melting loss in hearth

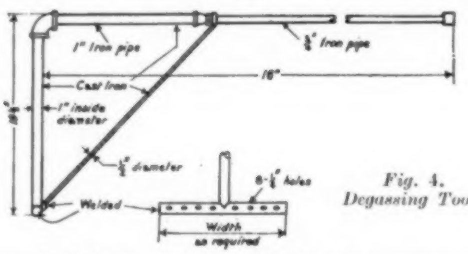


*Fig. 4. Degassing Tool.*

furnaces, including metal oxidized (and consequently unrecoverable), and shrinkage due to absorption by the walls and hearth, should not exceed 0·5 to 0·7%. Allowance is here made for the recovery of metal from dross and skimmings. The total yield of good ingots per heat will necessarily vary somewhat, depending on the details of operating conditions.

As is well known, aluminium is rather readily oxidised on melting, and flame regulation should be such as to avoid sharp "hard" flames, which impinge upon the metal. While it is difficult to control the atmosphere in overlying metal in an open-flame furnace, strongly oxidising flames should naturally be avoided. Adequate attention to the details of firing and furnace operation will ensure reasonably low melting losses.

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In the next article of this series the types and sizes of rolling ingots will be discussed.

*(To be continued.)*

# X-Rays and Metallurgy

By L. Pickup, B.Sc., (Lond.).

*Radiography has been successfully employed in regular commercial operation, and, in many instances, the results are considered of sufficient value to justify the installation of X-ray laboratories.*

DURING the last few years, X-rays have been used to study the internal structure of metals and alloys. The work done up to the present by this means has already given us a much clearer insight into their structure, and it has shown further what effects external agents, such as cold work, rolling, and alloying, have on this structure. While we are familiar with the general physical properties of metals, such as hardness, ductility, tensile strength, and so on, we have no explanation as to why certain properties are associated with certain metals and alloys. By using X-rays we can study the elementary units or cells of which these are composed, and it is only by such a study we can hope to throw any light on their physical properties as a whole. Up to now we have not got far in this direction, but this powerful method of analysis has opened up for us much new and fundamental ground. It is hoped that the account given here of this type of work will enable the metallurgist to understand more clearly the data and information concerning metallurgical questions, which are becoming more frequently published in papers and journals at the present time.

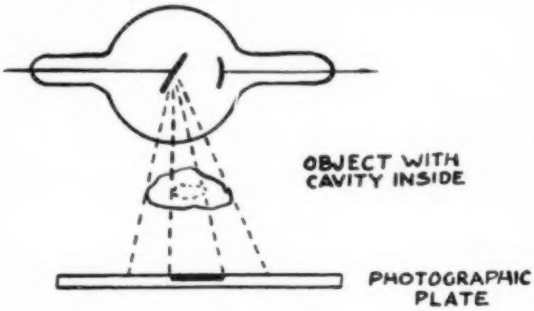



*Fig. 1.*

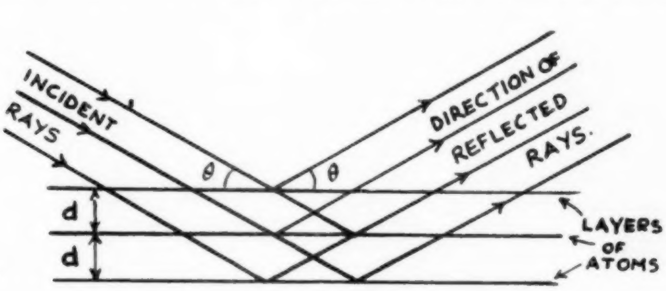



*Fig. 2.*

Since 1895, when Röntgen discovered X-rays, our knowledge of their properties and their applications to various problems has advanced very rapidly. From an early date medical science found applications which are well known to everybody to-day. It was at a later date that their value to industry became recognised. These applications are being still further extended, with useful and practical results. It was some years after their discovery that their true nature was found. It was Laue, together with Friedrich and Knipping, who showed that their nature was similar to that of light waves. This conclusion has now been fully corroborated, so that we now know that X-rays are ether waves having a wave-length, roughly, one-ten-thousandth that of light—that is, about $\frac{1}{10^8}$ centimetre.

The technique of their production is still advancing, but the principle in their production is the bombardment of a suitable target by swiftly moving electrons in a vacuum. The speed of these electrons can be imagined when an electric pressure up to, and in recent times over, 200,000 volts is used. The impact of the hammer on a piano string causes the string to vibrate and emit sound waves in all directions. An analogous action takes place when the electron hits a metal target which is built up of a complex system capable of vibration under certain conditions. Such targets are usually made of tungsten, chromium, molybdenum, platinum, copper, etc., depending on the kind of waves required, each metal emitting a different range of wave-lengths, in which are the characteristic radiations. Further mention will be made later of these radiations.

Having such a short wave-length, their penetrating properties can perhaps be indirectly conceived. It was really their excellent penetrating properties which suggested the first applications in making "shadow-graphs." Another important property for this purpose is that the rays travel outwards in straight lines from the target, and will therefore cast well-defined shadows. X-rays can be detected by various means, among which are (1) a specially prepared screen which the rays cause to fluoresce ; (2) a photographic plate which shows a darkening after development ; (3) the ionisation of gases, which makes them conducting. The penetration varies with the material, and the denser the material the less the penetration. According to Kaye ("X-Rays") the present practicable depths which can be penetrated in various materials are, roughly :—

4 mm. to 5 mm. of lead.
12 mm. of tin.
75 mm. of steel (carbon) or iron.
100 mm. to 150 mm. of aluminium and its alloys.
300 mm. to 400 mm. of wood.

An object having parts of varying density when placed in an X-ray beam casts a shadow which reveals the change in density.

Fig. 1 shows how the central part of the shadow will have on the plate a denser patch, due to the rays not being so much absorbed, owing to the cavity. By other exposures with the object in different positions, the exact locality and extent of the cavity can be fully determined. It is this differential penetration which is used in medical science to locate fractured bones and foreign matter in the body. Similar applications to metallurgy and engineering are to-day very numerous. The following may be mentioned as typical examples : Detection and location of hidden blow-holes and fillers in all kinds of castings. Flaws, seams, dross, and cracks in stampings, bars, forgings, etc. Faulty joints, due to bad electric and oxy-acetylene welding, soldering, and brazing. The examination and measurement of walls and cavities in castings of intricate design, like a motor-car cylinder. Hidden surfaces can also be examined for corrosion. Faults and fractures in covered wire can be detected, and in many instances, when the body or material is not too dense, the examination can be carried out without dismantling or even unpacking. The few applications enumerated here will readily suggest many more to the reader.

Even if X-rays could only be used in the above manner alone, their usefulness to industry can hardly be

exaggerated, but a more far-reaching and fundamental sphere of usefulness has been opened up. Work in this sphere has already thrown light on problems concerning the internal structure of metals, its forms and behaviour. Hitherto it was not possible to investigate such problems by any available means. Deductions from the results of Laue's work in 1912 pointed to a crystalline material being composed of a huge number of identical units or cells. From this time onwards this type of work has been developed

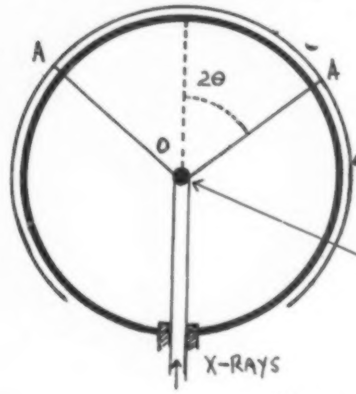



*Fig. 3.*

vigorously by a large number of workers, notably of whom are Sir W. H. and W. L. Bragg in this country, McKeehan and Hull in America, Debye and Scherrer in Germany, and Siegbahn and Westgren in Sweden. These unit cells are so small that no microscope can possibly be made to show them, as their size is of the order of that of the wave-length of X-rays. Such an attempt would be as futile as trying to draw a figure on paper with a pencil point 10,000 times bigger than the figure itself. X-rays enable us to ascertain the form and size of these elementary cells or units.

To understand the application of X-rays to the present problem it is necessary to outline some of the theoretical facts. The wave-length of the rays from a target covers a range of values, and in certain portions of this range the energy is more concentrated. The wave-length at each of these peaks of energy is called a characteristic radiation of the particular target. The two strongest characteristic radiations, which are those we are concerned about here, are called K $\alpha$ and K $\beta$. All the chief characteristic radiations for all the targets commonly used in X-ray analysis have been very accurately determined. Now, in all crystalline matter the atoms arrange themselves in certain planes, so that when the rays pass over these atoms, each emits a diffracted wave which spreads out all round it. When there are a number of similar atomic layers, parallel and equally spaced apart by a distance $d$, and these are exposed to X-rays with characteristic radiation $\lambda$, Bragg's Law gives the direction of the "reflected" rays in the form—

$$\lambda = 2\,d\,\sin\,\theta,$$

where $2\,\theta$ is the angle through which the rays are deviated. Fig. 2 shows this relation diagrammatically.

In practice the angle of deviation is determined, so applying the law, substituting the proper value for the wave-length, the value of $d$—the distance between the planes—is found. The use of the word "reflection" may be misleading in so far as the deviation of the rays is not due to the uppermost layer alone, but is due to the combined action of the adjacent layers, when the rays penetrate the body. In the ionisation method, which is the basis of the Bragg spectrometer, the region round a centrally mounted crystal or powder is surveyed with an ionisation chamber, which detects and measures the amount of X-rays reflected, by the current they produce in it. It is only at certain definite angles that the characteristic radiation is reflected—when Bragg's law holds; so that when the chamber indicates a sudden increase in current, certain planes are favourably oriented with regard to the direction of the rays. This method gives a measure of the relative intensities of the reflected rays from the different crystal planes, and this information can be used to find the positions of the atoms in a unit cell, when there are more than one kind, as in intermetallic compounds.

The usual method of examination of crystalline powders is a photographic one, in which the reflected rays register themselves on a suitably placed photographic film. The general form of the apparatus is shown in Fig. 3, where the powder is mounted in the centre of a cylindrical camera, usually made of brass, and around which is fixed a film. O A and O A$^1$ are the reflected beams from one set of planes. The angle $2\,\theta$ is found by measuring the arc A A$^1$ and the radius of the camera. Although the particles of the powder are oriented in all directions, for planes of a given $d$, it is only when the Bragg relation is obeyed that reflection takes place. The photographs in Fig. 4 have been taken with this type of apparatus, and were produced with aluminium and copper respectively, in powder form. These will be discussed later. For metals and alloys this powder method is very convenient, since it is not necessary to obtain single crystals, the preparation of which is usually both tedious and difficult.

The third-method X-ray analysis is known as the rotating crystal method, which is self-descriptive. For certain work this method is sometimes the only one available. For further and more complete details of these and other methods, reference must be made to text-books and original papers.

We now pass on to the forms and means of describing crystal structures. Fig. 5A shows a cube with atoms in the eight positions A, B, . . . H, and one at the centre of each face as shown. Here we have a form known as a face-centred cube. If we have a cube with eight atoms as before at the corners, and one atom in the centre (see Fig. 5B), we have a body-centred cube.

In the cube crystals the various planes are defined in the following manner. Choose a point, such as E, as origin, and E X, E Y, and E Z as axes of reference. Then to define a set of planes, take their intercepts on these three axes in order. The reciprocals of these lengths—using the cube side as the unit of length—give the Miller indices ($h\,k\,l$). For example, the set of planes parallel to the plane B F G C make intercepts of E F on the E X axis, but are parallel to the other two axes. The reciprocals of these are, therefore, 1, 0, 0, giving the indices (1 0 0). The set of planes parallel to D C G H and A B C D have indices (0 1 0) and (0 0 1) respectively. Similarly, it will be found that the planes parallel to D B F H and A F H have indices (1 1 0) and (1 1 1). In X-ray work the indices ($h\,k\,l$) refer to the distance each plane is from its neighbour in its own set. In a body having a cubic crystalline structure there are a very large number of these cubes, each identical in structure and fitting together exactly in all directions. The side of each cube is usually called $a$, and the distance apart of

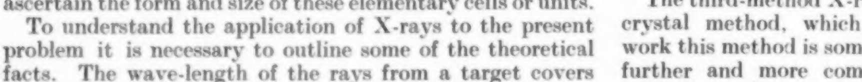


*Fig. 4a.—Aluminium.*

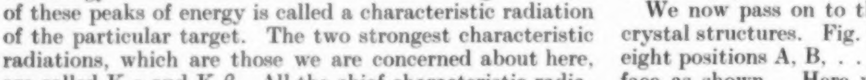


*Fig. 4b.—Electrolytic Copper.*

a set of parallel planes with Miller indices ($h\ k\ l$) is expressed by the formula—

$$d_{(hkl)} = \frac{a}{\sqrt{h^2+k^2+l^2}}$$

Mathematically we can find the conditions for the indices for face-centred and body-centred cubes. They are : (1) in the face-centred cube $h$, $k$, and $l$ are all odd or all even ; (2) in the body-centred cube the sum of $h\ k\ l$ is even. Such a criterion is often used to distinguish between these two kinds of cubic form.

On comparing the photographs in Fig. 4 it will be found that the sequence of lines is exactly the same, except that the lines of photo. 4*b* are displaced outwards. This comparison shows clearly that aluminium and copper have the same form of structure—face-centred,—but that the size of the cube is different. The sides are $4 \cdot 04 \times 10^{-8}$ cms. for aluminium, and $3 \cdot 61 \times 10^{-8}$ cms. for copper. When the units are made up of two kinds of atoms, as in intermetallic compounds, the intensities of the lines throw light on the relative positions of the two kinds of atoms within the unit cell, because the scattering power of the atoms is different.

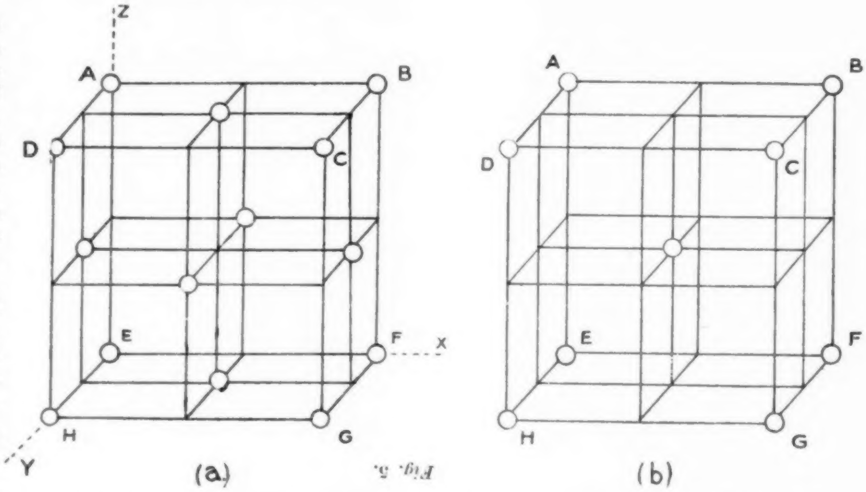



*Fig. 5.*

The following summary gives approximately the cube sides for some of the common metals :—

FACE-CENTRED CUBIC STRUCTURE.

| | |
|---|---|
| Aluminium | $4 \cdot 04 \times 10^{-8}$ cms. |
| Iron (γ) | 3·63 ,, |
| Copper | 3·61 ,, |
| Silver | 4·08 ,, |
| Platinum | 3·91 ,, |
| Gold | 4·08 ,, |
| Lead | 4·93 ,, |

BODY-CENTRED CUBIC STRUCTURE.

| | |
|---|---|
| Vanadium | $3 \cdot 04 \times 10^{-8}$ cms. |
| Chromium (a) | 2·87 ,, |
| Iron (a) | 2·86 ,, |
| Molybdenum | 3·14 ,, |
| Tungsten | 3·15 ,, |

There is another form of crystal structure which is frequently found in metals. This is known as the closepack hexagonal. The atoms occupy positions as shown in Fig. 6.

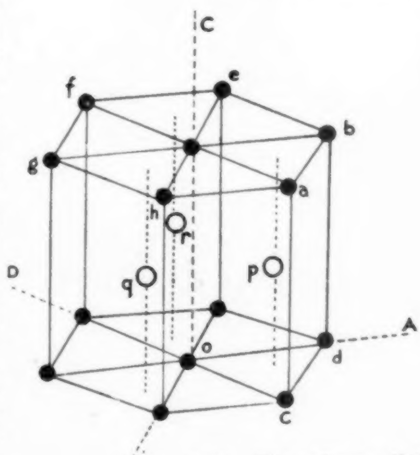
The axes of reference to define the planes in this structure are O A, O B, O D, and O C, where the first three are at right-angles to O C and make an angle of 120° with one another. The set of planes parallel to $a\,b\,c\,d$ is then the $(1\,0\,\bar{1}\,0)$ planes, the four indices being obtained from the intercepts on these axes in the same way as for the cubic form. It will be noted that one index is negative ; this is because the plane cuts the O D axis on its negative side. For any plane of this system, $h + k = i$, where the indices are ($h\ k\ i\ l$). Similarly, the set of planes parallel to $a\,b\,e\,f\,g\,h$ will have indices $(0\,0\,0\,1)$. The ratio of the length $c\,a$ to $o\,d$ is called the axial ratio ($c$). The length O $d$ or $c\,d$ (both are equal) is called $a$. The following table gives roughly the values of $a$ and $c$ for metals which have this structure :—

CLOSE-PACKED HEXAGONAL STRUCTURE.

| | $a$ | | $c$ |
|---|---|---|---|
| Magnesium | $3 \cdot 20 \times 10$ cms$^{-8}$. | .. | 1·62 |
| Titanium | 2·95 ,, | .. | 1·59 |
| Cobalt | 2·51 ,, | .. | 1·59 |
| Zinc | 2·64 ,, | .. | 1·86 |
| Cadmium | 2·97 ,, | .. | 1·89 |

Tin (grey) and antimony crystallise in the forms known as tetrahedral cubic and rhombohedral hexagonal respectively, both of which are modifications of the forms already given.

From X-ray measurements the density of a metal can be calculated, and the agreement with that usually accepted (obtained by the ordinary method) gives much support to the deductions about crystal structure derived from X-ray analysis. As an example we will consider the face-centred cube, Fig. 5A. When these cubes are packed together the atom in position A is shared by eight of these cubes, so that this atom, so to speak, has one-eighth part in each cube. The other seven atoms placed at B, C, D, E, F, G, and H are like the one at A, and each contributes one-eighth of an atom to the cube. The total contribution of these eight atoms is therefore one atom. Considering the six atoms in the centre of the faces, each of these is shared with two cubes, so that each contributes half an atom to one cube. We see, then, that the cube as shown has the mass equal to that of four atoms. From the table of atomic weights relative to hydrogen, and knowing the actual mass of the hydrogen atom, we can find the actual mass of cube



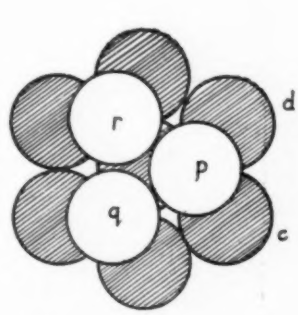




*Fig. 6.*

unit. The volume of the cube is clearly $a^3$. The density is given by the expression—

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

(*Continued on page* 108.)

# Iron and Steel Foundry Practice

By Ben Shaw

## Part VII.

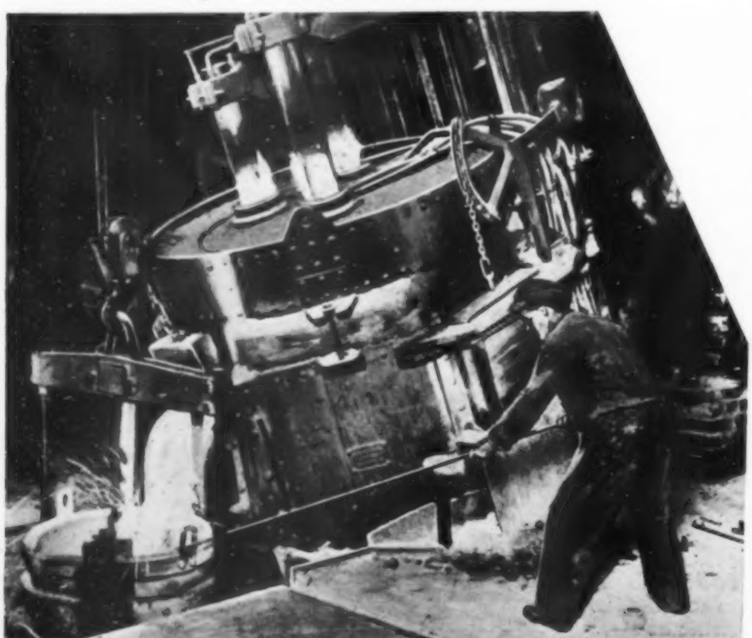
### Electric Furnaces for Melting Steel.

THE use of the electric furnace has developed considerably during recent years, due in a large measure to the increasing use of alloy steels, for the melting of which the electric furnace offers many advantages. Electricity has been commonly regarded as an expensive melting medium, probably due to the fact that it has been customary to compare the cost of generating a given number of B.th.u. of electrical energy with the cost of producing a similar number of heat units by other means, without making adequate allowance for the higher efficiency obtained from electricity in a properly designed furnace. The thermal efficiency is low in fuel-fed furnaces, while the transfer of heat by electricity is relatively high, and much less fuel may be necessary to generate the amount of electricity for melting than is required when using the fuel direct. However, even though the cost of electricity measured in B.th.u. may be greater, quite a number of other factors are favourable to its use, and these advantages have firmly established the electric furnace as a melting unit. Among the advantages associated with the use of electric furnaces are cleanliness in regard to melting, accuracy of control, and uniformity in the transfer of heat. The ease of operation and the absence of combustion gases are other favourable factors, and add considerably to the value of these furnaces, particularly for steel.

Electric melting appliances for steel are divided into two main types, and are generally known as arc and induction furnaces. The arc furnaces may be subdivided into two classes: those that develop heat as a result of an arc struck between two electrodes, and those in which an arc is formed between an electrode and the charge to be melted. Many furnaces are constructed which embody a combination of these features and in which the current is carried through electrodes to the bottom of the hearth. Either continuous current or alternating current may be used, but alternating current is now almost universal, in view of the fact that generation of heavy continuous currents at low voltages, between 75 and 100, involves costly generators, and, in addition, difficulties are likely to arise as a result of electrolytic action. With alternating current there are no such difficulties in providing the heavy currents necessary, as static transformers are used. One of the principal advantages of alternating current over continuous current is due to the fact that the voltage can be readily transformed and varied to meet requirements. It is economical to transmit electricity at a high voltage, but for use in melting furnaces it must be at a low voltage. One of the features of electric furnaces, providing they are designed on the right lines, is that temperature is always under the control of the operator. The use of alternating current makes this comparatively easy, as the voltage between electrodes, or between an electrode and the charge, can be varied by means of selector switches which control the temperature.

*Fig. 4.—A 6-ton Greaves-Etchell Furnace.*

*Fig. 1.—A 6-ton Heroult Furnace.*



Of the arc type of steel furnaces those in most common use in this country are the Heroult, Electro-Metals, Greaves-Etchells, and Stobie, and it may be as well to make general reference to this type of furnace before giving consideration to each design.

Arc furnaces may have either vertical or horizontal electrodes, and the heating effect takes place partly by radiation from the arc and partly by the resistance of the metal to the passage of the electric current, this resistance heating being a predominant feature of the furnaces which are provided with a conducting hearth. The majority of furnaces in use are of the vertical electrode type, and three-phase current is more generally employed, because the equipment required is less expensive, and the control of the furnace operations is more simple than the single-phase or two-phase current. Furnaces for three-phase current are provided with three electrodes connected to transformers, and the molten metal or the hearth of the furnace is then used as the unconnected or neutral point of the system. Furnaces with a conducting hearth are considered to be more

satisfactory for the manufacture of special alloy steels, as the hearth being kept hot aids in the circulation and mixing of the metal. In high-grade alloy steels it is important that a rapid diffusion of the added alloying elements should take place throughout the mass of metal contained in the furnace, and those having a conducting hearth facilitate this object. It must be mentioned, however, that this type of furnace is more costly in erection and in maintenance, and the loss of heat and electric current from the conducting hearth is greater than with other types of furnaces. In view of the fact that their value is associated more with high-grade alloy steels, the increased working costs are perhaps not of such vital importance.

### The Heroult Furnace.

The earliest to be used for steel melting commercially, was the Heroult, which was designed and perfected in the United States by P. Heroult, about 1899, and which, with minor modifications, corresponds to this make of furnace in use to-day. The first installation of the Heroult furnace in this country dates back to 1909, and now there are probably more of these furnaces in use than any other design. The furnace is of the vertical electrode type, with a non-conducting hearth, and is designed to operate on a single-phase, two-phase, or three-phase supply at any frequency. It consists of a refractory hearth built inside a sheet-steel casing, which is mounted on rockers for convenience in tilting to pour and slag the molten charge. The electrodes, of which there may be two, three, or four, are held in position by means of couplings which allow them to be moved up or down by means of screw gearing fixed to the furnace body. The gearing operating the electrodes is under the direct electrical control of the operator, who can regulate their position at will. The electrodes pass through the roof of the furnace and come into contact with the charge. The heat is generated from an arc produced between the electrode and the charge, and between electrodes. This furnace can be used with either an acid or basic hearth, the former being a convenience for steel foundries when a high degree of refining is unnecessary. The acid hearth is more economical, and in a Heroult furnace will last 2,000 to 2,500 melts, while a basic hearth does not, as a rule, last more than about 1,000 melts. The outstanding advantages of the arc furnace for the production of steel result from the application of an intense heat in a controlled atmosphere, which permits the slag being maintained in a high degree of fluidity. When a high degree of refining is necessary, involving a basic hearth, sulphur elimination is positive and complete, as is also dephosphorisation, and these conditions ensure a uniformly high quality of product.

Although, in design, the modern Heroult furnace is not materially altered from the original design, a feature of recent installations is the increase in the power input, with a resulting decrease in the melting time. This is of especial advantage in small foundries, as there is generally no need for a long refining process, and floor space is saved by a rapid succession of small heats, and the high temperatures required for the production of light castings can readily be attained.

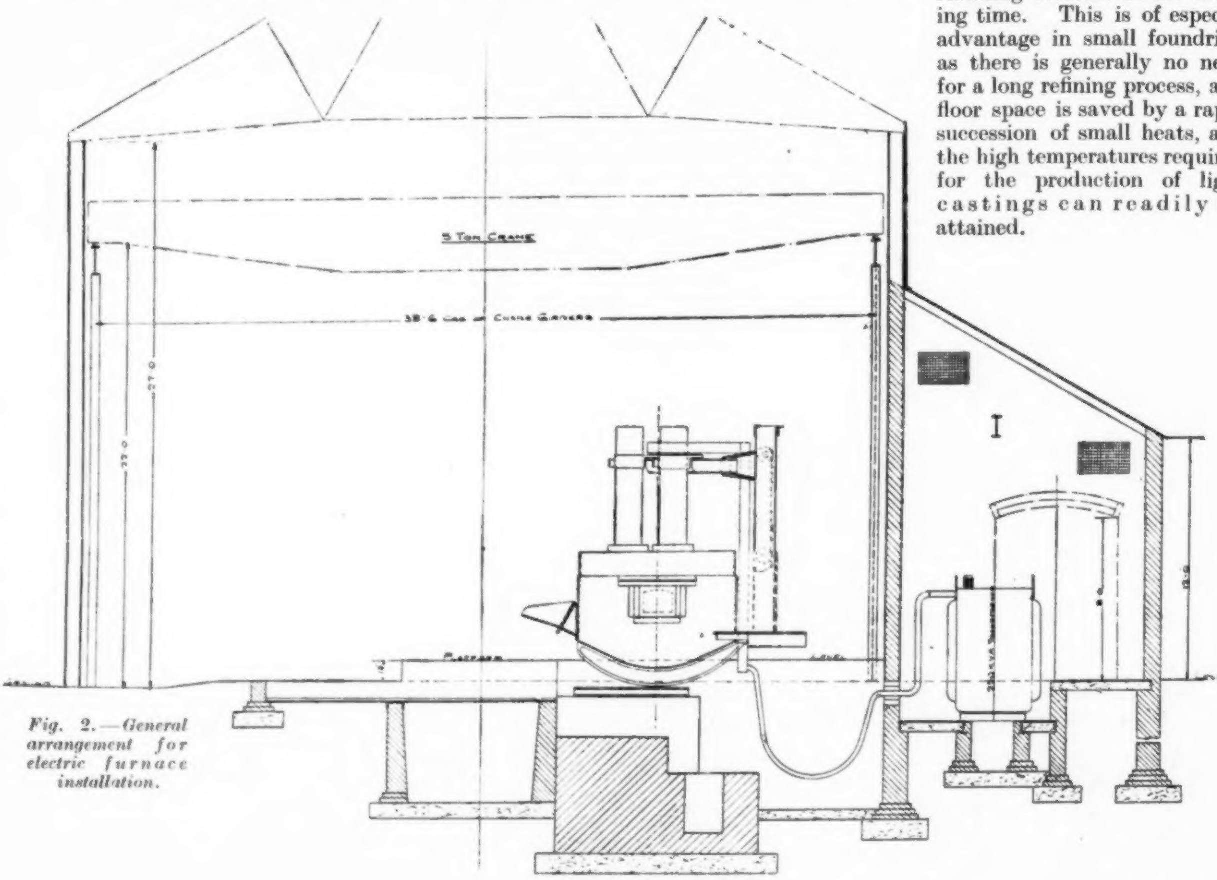


*Fig. 2.—General arrangement for electric furnace installation.*

As a numerical example of the benefit in power consumption derived from an increase in the rating of these furnaces: A 750 K.V.A. 3-ton furnace with efficient automatic regulation will give a power input of about 675 units per hour, and will have a power consumption of approximately 750 units per ton. The total units for a charge are, therefore, 2,250, and the time taken to melt will be $3\frac{1}{3}$ hours. As the efficiency of this furnace will be approximately 60%, the losses are equal to 900 units.

If the K.V.A. is increased to 1,150, with a power input at the rate of 1,000 units per hour, the time taken to melt the same weight of metal would be 1·8 hours, and the total units 1,800. The current consumption per ton will be reduced to 600, which shows a saving of 20% on the original figures, besides increasing the output.

There has also been a marked improvement in automatic regulators in recent years, and no hand regulation is now necessary when melting cold scrap. The fluctuations of

current can be controlled by the regulator, even when the furnace is on full load for melting heavy scrap. The unit consumption consequently shows a marked improvement by maintaining full load from the start.

Fig. 1 shows the general arrangement of a 6-ton furnace, which is suitable for fairly large castings, while Fig. 2 illustrates the layout for a furnace which is used for light

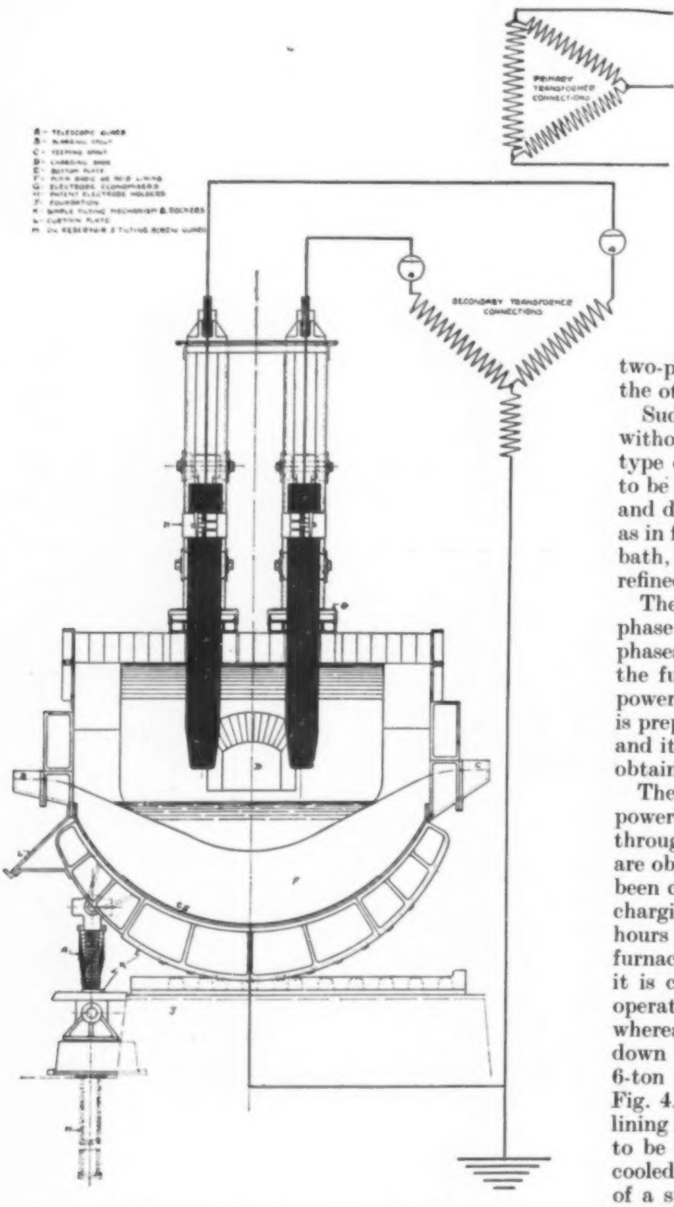



Diagram of "Greaves-Etchells" System.
*Fig. 3.*

castings. The transformers are generally arranged with two tappings, the higher voltage being employed for melting, while the low voltage is used during the refining period.

The special advantages of the Heroult design, which have earned for it considerable popularity, are its ease of operation and low maintenance. No complicated switchgear is required to obtain a balanced load on polyphase supplies, and the absence of bottom electrodes increases the life of the lining and facilitates its repair and renewal. The lining may be acid or basic, and for some operations the former is not only cheaper, but more suitable.

## The Greaves-Etchells Furnace.

This furnace is of the vertical electrode type, with a conducting hearth. It can be operated either with two- or three-phase current. The special patented features of this furnace provide means for converting the unsymmetrical, and consequently unbalanced, currents of the secondary transformer systems, so that there may be a balanced load on the high-tension supply phases. A diagram of the system is shown in Fig. 3. It is claimed by the inventors that their system of construction embodies many advantages.

The charge, for instance, is rapidly melted, and very uniformly heated, owing to the continuous circulation of the metal, and heat is generated both above and below the bath, and can be regulated over a wide range. No cold bottom is encountered.

The hearth of the furnace is at least 20 in. thick, and forms a very safe container of molten steel. With reasonable care it will last over 1,000 heats. Further, there are no water-cooled studs or embedded carbon electrodes in the hearth to conduct away energy. It is suitable for two-phase or three-phase current, and if one arc be broken, the other arcs are not affected.

Sudden overloads are more effectively "buffered" without the use of external reactances, than in any other type of furnace. The system allows an even temperature to be obtained throughout the whole of the furnace charge, and does not punish the roof and walls to the same extent as in furnaces in which the whole heat is generated over the bath, and the energy consumed per ton of steel melted or refined is as low as that with any other type of furnace.

The standard type of Greaves-Etchells furnace for three-phase current, possesses four electrodes, connected to two phases of the three-phase current supply. The whole of the furnace lining is connected to the third phase of the power supply, and acts as one large electrode. This lining is prepared exactly as the lining of an open-hearth furnace, and it is claimed that in some cases 2,000 heats have been obtained from the one lining.

The charge lies directly between the three phases of the power, and as the lining is also heated by the passage through it of the current, rapid melting and good mixing are obtained. Heats for castings, using a basic lining, have been completed, it is stated, in slightly over an hour from charging, with a power consumption of under 500 kw.-hours per ton of steel in the ladle. With the four-electrode furnace, should any trouble arise with one of the electrodes, it is claimed that it is still possible to carry on melting operations with the remaining two or three electrodes, whereas other types of furnace would be compelled to shut down under these conditions. An illustration showing a 6-ton Greaves-Etchells furnace in operation is shown in Fig. 4. These furnaces can now be prepared with an acid lining for the hearth. Such a lining was formerly considered to be non-conducting, and only to be used with a water-cooled stud to maintain electrical contact ; but as a result of a special study of the problem, a composition for conductive acid linings has been discovered, which has given satisfactory results.

## The Electro-Metals Furnace.

The Electro-Metals furnace is also of the conducting hearth type, its main developments having been effected in this country. The hearth is basic, the steel sheet being lined with magnesite and silica brick, upon which is a bed of dolomite, which is electically conductive when heated.

These furnaces are made for either two, three, or four upper electrodes. When two-phase current is used on the two-electrode furnace, the transformers are Scott connected, and the neutral of the two-phase supply is connected to the hearth of the furnace. When four electrodes are used a four-phase supply is obtained from a three-phase

primary by a suitable transformer arrangement, and in this case also the neutral of the four phases is taken to the hearth of the furnace.

The illustration, Fig. 5, shows a 20-ton, four-phase furnace, where the four upper electrodes are disposed over a circular hearth in such a way as to give the best distribution of the heat generated by the arcs, but for small foundries, manufacturing high-quality castings, the smaller two-arc electric furnaces are more common. These furnaces are operated in precisely the same way as other furnaces of this type.

### The Stobie Furnace.

Much development work in connection with electric furnaces has been done by Mr. V. Stobie, and has resulted in the design of the furnace associated with his name. These furnaces are of the vertical electrode arc and the high-frequency induction types, and can be adapted for single-, two-, or three-phase, whichever is available. Fig. 6 shows a 2-ton arc furnace in course of erection, while Fig. 7 shows one of larger capacity. For furnaces up to 6 tons capacity, two electrodes are usually employed ; above this capacity, four electrodes, connected up in pairs, are customary. Some large furnaces are fitted with four carbon electrodes, three of which are jointed up to three terminals of a star-connected three-phase current supply, and the fourth to the neutral point of the system. Mr. Stobie is of the opinion that the neutral point is only required because a three-phase current, when used for electric furnace work, can never be balanced, and a certain part of the current will always travel back via the neutral point within the furnace and develop heat. The largest Stobie designs have six electrodes, the system being three-phase, with two electrodes in series in each phase.

One of the chief features of the Stobie furnace is the patent economiser, which seals up each electrode opening in the roof. These consist of light metal cylinders, a few inches more in diameter than the electrode and about 2 ft. in length. A cylinder is fixed on the furnace roof about each electrode, and the top is sealed with a plate, through the centre of which the electrode passes to the furnace. It has been proved that in most furnaces the temperature of the electrodes about 2 ft. above the roof is seldom such that they burn, and it is at this point that a permanently good seal can be made around the electrodes.

This economiser is also constructed in telescopic form suitable for furnaces having a gibbet form of electrode holder. The saving in current effected by these economisers is 50 to 150 units per ton, according to the type of steel manufactured. The period of melting is reduced about 10%, and the electrode consumption for fully refined carbon and alloy steels has been brought down to 6½ lb. per ton over a full year.

The advantages claimed to result from these economisers are many, and it is emphasised that no cold air is drawn into the furnace round the electrodes, and no flame or highly heated air burns away the electrodes above the roof. A reducing atmosphere is, therefore, maintained within the melting chamber, and the electrodes can be smaller in diameter for a given current supply. The life of the roof is increased, while the electrode gear over the furnace does not become hot. In consequence of the exclusion of free air from the furnaces, and the absolute control which this permits over metallurgical operations, scrap steels containing such oxidisable elements as tungsten, chromium, manganese, and even vanadium, can easily be melted without losing their special elements from the bath. Further, the increased output from the plant reduces the labour required for a given output of steel.

Other distinguishing features of this furnace are that the electrode and cable-carrying superstructure is formed by a rigid bridge secured on all sides to the furnace, and that the whole furnace, whether large or small, is mounted on stoutly built roller bearings.

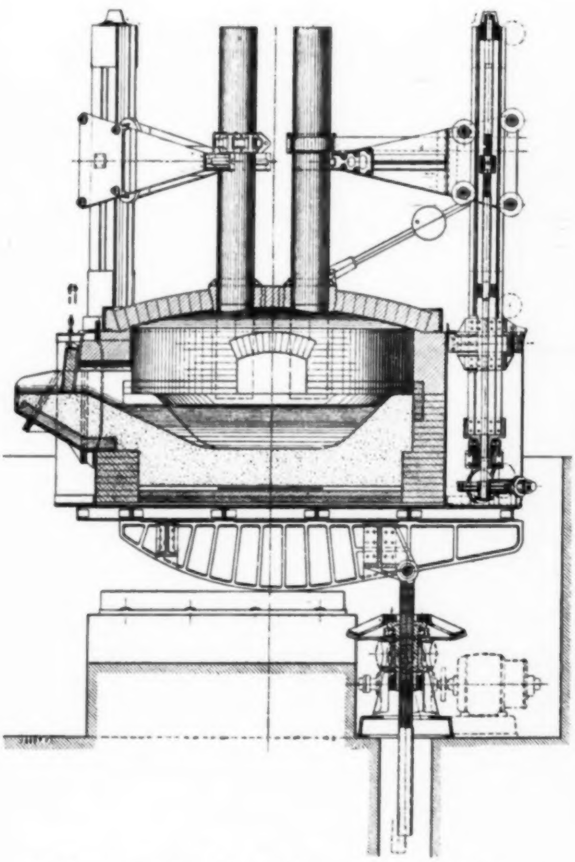


*Fig. 5.—Arrangement for a 20-ton Electro-Metals furnace.*

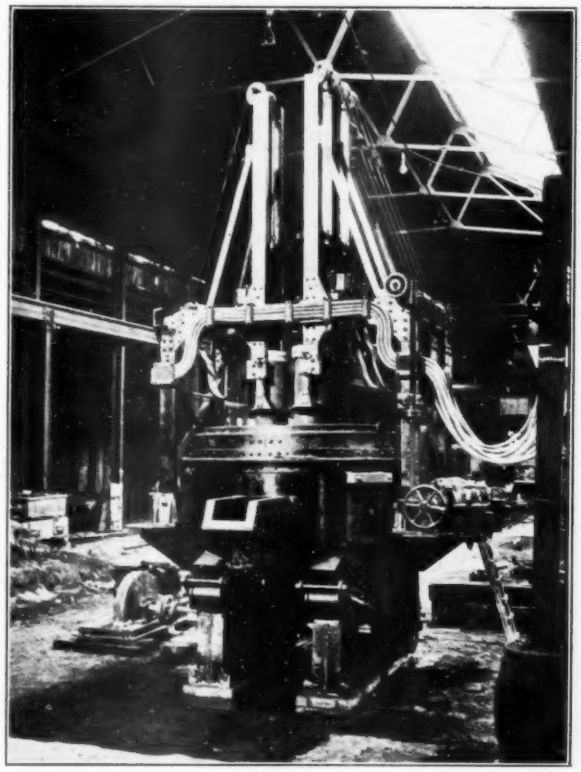


*Fig. 6.—A 2-ton Stobie arc furnace in course of erection.*

### The Induction Furnace.

In this type of furnace the heating is effected by current induced in the metallic charge itself, for which purpose alternating current is necessary. The heat is generated by the passage of the secondary or induced currents through the charge. There is no loss of heat due to transmission by radiation and conduction, as the heat is generated in the material itself, and is distinct from the arc-furnace type, in which the heat is generated in the arc and must be conveyed to the metal bath by radiation or conduction. In 1900 the late Dr. Kjellin introduced a furnace of this type, which was able to make high-grade steel, but it was not a commercial success, and is not now in use.

A more recent innovation in steel-foundry practice is the coreless, or, as commonly known, the high-frequency induction furnace. Two such installations have been in operation in this country for some time, and it offers certain advantages over the arc furnace.

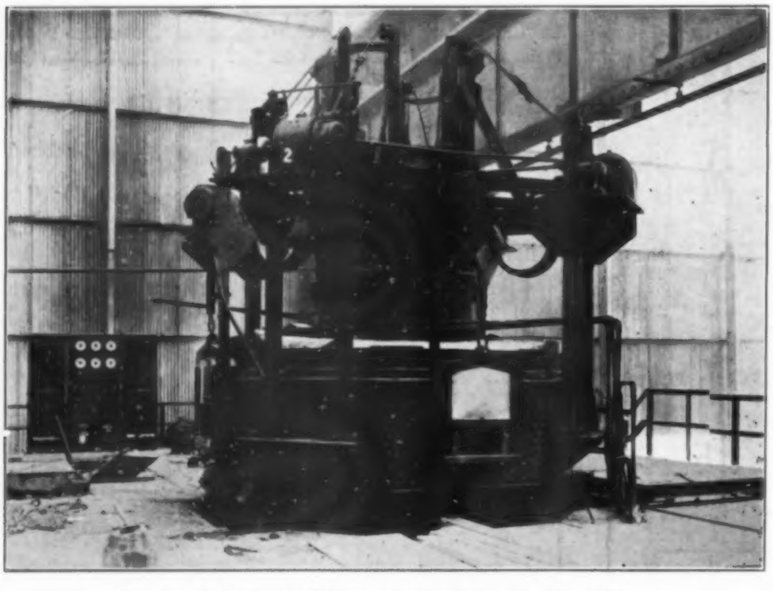


*Fig. 7.—A 15-ton Stobie arc furnace in course of erection.*

For the production of light steel castings the metal must inevitably be superheated in other processes to allow of the last part of the charge being hot enough to run. The application of this induction furnace, however, does away with this necessity, as the current can be kept on during casting, so that the metal is maintained at a uniform casting temperature throughout the operation. The furnace is also arranged to tilt about an axis through the pouring spout, and the metal may be cast directly into moulds, which is advantageous in cases where large quantities of castings are required of the same shape and size. Where alloys of a complex composition, such as magnetic and austenitic corrosion-resisting steels, have to be cast, the certainty of obtaining the calculated composition is an added advantage.

The process possesses all the advantages of the small converter, as a rapid succession of small heats may be obtained, and the pouring direct into moulds saves ladle costs or heavy labour charges, if hand-shanks are used, while, on the other hand, the high metal losses of the converter are avoided. Up to now this type of furnace has only been used for the plain melting of scrap or virgin metal, but its refining possibilities have been explored, and in the near future it is not going too far to say that it will play an important rôle in steel-foundry practice.

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The installation of furnaces and plant to cope with the increasing demand for "Enox" hacksaws has caused encroachment upon the warehouse space at the Greenwich Works of Fry's (London) Limited, and in future the Head Office and Warehouse will be combined at 24/5, King Street, Minories, London, E. 1. Tel. Royal 6152.

## X-Rays and Metallurgy

*Continued from page 103.*

Taking copper, which is face-centred, and which has atomic weight = 63·6, and $a = 3{\cdot}61 \times 10^{-8}$ cms., we have, on substituting in the expression for the density—

$$\text{Density} = \frac{63{\cdot}6 \times 1{\cdot}66 \times 10^{-24} \times 4}{(3{\cdot}61 \times 10^{-8})^3}$$
$$= 8{\cdot}97 \text{ grms. per c.c.}$$

(The mass of the hydrogen atom is $1{\cdot}66 \times 10^{-24}$ grms.).

It will be found that this figure is within a few hundredths per cent. of the best accepted value for the density of copper by other methods.

The density of the body-centred metals can be worked out in the same way, except that the cube is equivalent in mass to two atoms. Conversely, if the density is known, the number of atoms per unit cell can be calculated, and thus, by knowing the density of the $\gamma$ phase of brass, and the size of the cube unit, it is found that the number of atoms in the unit is 52—20 of copper and 32 of zinc. The structure of this phase is a modified body-centred cubic.

On calculating the distance of nearest approach of the atoms for any metal, it is observed that this distance is practically constant for all the combinations in which the metal is found. Use is made of this fact when placing atoms of two kinds in complex crystal units, such as the $\gamma$ phase of brass.

As the density changes with temperature, so the lattice side changes, so that it is possible to ascertain the coefficient of thermal expansion by X-rays, and further to determine if this coefficient is the same in all directions. It is already known that crystals can have different physical properties in different directions. The reflections from the planes when the crystal is heated to a high temperature are not so well defined as those at atmospheric temperature. This is due to the thermal agitation of the atoms themselves, which move about a mean position in their planes. The planes thereby have "thickness," so to speak. Poor reflections are also obtained when the crystals have become distorted, resulting in the planes possessing "thickness."

When an X-ray powder photograph is taken of an alloy with a composition representing two phases, each phase gives its own reflections independent of those of the other. This is a means of detecting a two-phase region, independent of any microscopical examination.

There is no doubt that the study of crystal structure by X-rays is giving a great accumulation of data concerning metals, alloys, solid solutions, intermetallic compounds, and the effects of cold work, and other agents on the structure, all of which aid us more fully to understand and predict the behaviour of metallurgical products under every kind of industrial treatment and usage.

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### Important Arrangement in the Manufacture of Electric Furnaces.

We are informed that an arrangement has been made with the Hevi Duty Electric Co., Milwaukee, U.S.A., whereby all patents granted, pending, and all further improvements and processes, will, so far as Europe and British Possessions (exclusive of Canada and Newfoundland) are concerned, be operated and manufactured in England by Messrs. Gibbons Brothers, Ltd., Dibdale Works, Dudley, and Wild-Barfield Electric Furnaces Ltd., at their works.

There can be no doubt that this arrangement, which covers the construction of patented rotary hearth, regenerative counterflow furnaces, and numerous other types of mechanically operated electric furnaces, together with the close interchange of engineering and manufacturing experiences, will be of considerable value to users of electric furnaces for large and small production. It is of interest to note that no change is made in the Directorate, Staff, or Capital of either Messrs. Gibbons Brothers, Ltd., or Wild-Barfield Electric Furnaces, Ltd., which remain, as previously, entirely British.

# Brinell, Rockwell and Scleroscope Hardness of Non-Ferrous Metals*

By O. Schwarz

THE Brinell test occupies such an established position among methods of hardness testing that the Brinell hardness number is a generally accepted measure of hardness, and it is customary to grade metals accordingly. Although Brinell hardness does not in itself represent a new property of the metal, but merely the mean resistance to deformation, it is none the less valuable, since, owing to the simplicity of the procedure, it rapidly gives an insight into the strength in deformation of a metal. Its basic significance lies in the fact that with steel the resistance to deformation indicated by the Brinell hardness number corresponds to the tensile strength. Consequently for this material the Brinell hardness is a convenient means for estimating this important property, and by its aid the whole course of the deformation process can be traced, as the tensile strength lies close to the elastic limit, and some idea of the elongation can also be gained, in so far as the condition of the steel is known.

With non-ferrous metals, however, this simple connection does not exist,[1] but the contrary appears to be the case, as two different metals having the same tensile strength may have different Brinell hardnesses; it is, nevertheless, true that in such cases the metal with the lower elastic limit has the lower Brinell hardness number, so that even non-ferrous metals can be arranged in order of increasing strength by means of their Brinell hardnesses. In practice, account must be taken of the fact that the total resistance to deformation cannot be determined from a single hardness number, and that in consequence the load must be standardised if comparisons of Brinell hardness numbers are to be made. This does not give rise to further errors, such as is the case when a metal is judged solely on its tensile strength without any exact knowledge of its elastic limit or elongation on fracture.

## Rockwell Hardness.

When carrying out Brinell tests, particularly when a large number have to be made, the time taken in measuring the impressions becomes unpleasantly noticeable. The Rockwell hardness test[2] does not suffer from this disadvantage, the depth of the impression being directly shown on a dial in the ratio of 1 : 5. The required load is applied by means of weights with the necessary leverage. In itself measurement of the depth is not a new departure, having previously been used by Martens, but to Rockwell is due the credit of having worked out a practicable apparatus for the purpose. The depth-measuring process had previously been rejected (in Germany) owing to the inherent sources of error, but where numerous tests have to be made, the advantage of the rapidity with which readings can be made is so great that when it is only a question of comparative tests, the inaccuracies bound up with the method may be disregarded. The process was further developed in America, though there were several hardness testing machines of German manufacture working on the principle of depth measurement, which, moreover, had the advantage of permitting tests to be made with the loads standardised for the Brinell test. The process depends on the measurement of the difference between the depths due to an initial and a final load, the initial load being used to ensure that effects due to the state of the surfaces are absolutely ruled out. A further difference lies in the use of much smaller balls, so that considerably greater loads than those standard for the Brinell test must be used. The difference in the evaluation of the hardness numbers obtained by the two methods is this: The Brinell number is given by $1 : t$, where $t$ is the depth of impression, the Rockwell number by $A - t$, where $t$ is the depth of impression in 1/500 mm., and A is a fixed value, which is 130 when the steel ball is used, and 100 when the diamond cone is used.

Table I. gives particulars of the various ball sizes and loads used for Rockwell hardness tests. In general, a distinction is made between two series of Rockwell numbers —Rockwell hardness C, determined with a 150 kilog. load and the diamond cone, and Rockwell hardness B, determined with a 100 kilog. load and a $\frac{1}{16}$ in. ball. For the C hardness the scale begins at 100, for the B hardness at 130 or $-30$. When testing steel with a ball, hard pieces flatten the ball and give small depths of impression, and consequently negative hardnesses; substitution of the diamond cone for the steel ball overcomes this trouble. In course of time the procedure was widened, other loads and balls being used, so that it was no longer sufficient merely to distinguish between B and C to show the conditions of the test, but the size of the ball and the load had to be given, as in the Brinell test. The letters B and C now merely show that the hardness numbers were obtained by subtracting the depth from 130 or 100 respectively (see Fig. 1). Although the depth measurement process has been rejected for a considerable time owing to its theoretical inadequacy, it must be admitted that from the practical point of view the Rockwell hardness test is highly satisfactory as a means of comparison. From the foregoing description and from what follows, it is obvious that the Rockwell hardness numbers give a different standard from that given by Brinell hardness numbers, and, what is more important, the difference in the Rockwell hardnesses of two metals will not be the same as the difference in their Brinell hardnesses.

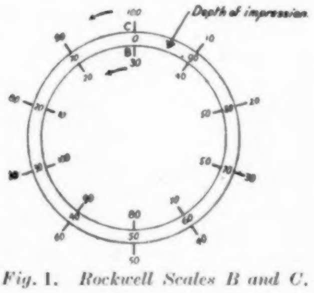



*Fig. 1. Rockwell Scales B and C.*

For a critical review of the Rockwell test, and the practical utility of the process, it was of considerable importance to determine the relation between Rockwell and Brinell hardness for steel (in the first place) with an exactitude sufficient for practical purposes. This was mainly done by American workers, in particular Petrenko,[3] and by Wallichs and Schallbroch[4] in Germany. The need for a knowledge of this relation for non-ferrous metals also gave rise to comparative experiments on the most important of these metals.[5]

## Results of Experiments.

Brinell hardness numbers are based on a load equal to $10\ D^2$, though a load equal to $5\ D^2$ gives almost the same uniformity. Table II., which contains the full results of the experiments, shows the difference in the hardness numbers obtained with the different loads.

The deviation of the Brinell hardness numbers obtained with the 2·5 mm. ball from those obtained with the 10 mm. ball with the same proportional load, gives an insight

* Translated from "Brinell-, Rockwell- und Skleroskophärte bei Nichteisenmetallen" by I. Boodson, *Z.f. Metallk*, June, 1930.

into the extent to which the hardness of the metal varies, a circumstance which is particularly noticeable when small balls are used, as is the case with the Rockwell machine.

The relation between the Rockwell and the Brinell hardnesses of the metals investigated can be represented sufficiently accurately for practical purposes by the following equations, the error being seldom more than ± 5%.

Comparison of the two curves shows that with annealed and rolled non-ferrous metals with a Brinell hardness of 50 to 180, Rockwell tests, carried out with the heavier load ($\frac{1}{16}$ in./100 kilog.) allow of greater accuracy than does the standard Brinell load of 10 D², owing to the flatter course of the curve The latter load gives a flat curve only with very soft metals (Brinell hardness below 50) For this

TABLE I.

Customary Loads and Ball Sizes for Rockwell Hardness Tests.

| Load, Kilos. | 60 (c) | 62·5 | 100 | 100 (b) | 150 (c) | 150 (b) | 187·5 |
|---|---|---|---|---|---|---|---|
| Ball diam. D | $\frac{1}{8}$ in. (3·19 mm.) | 2·5 mm. | $\frac{1}{8}$ in. | $\frac{1}{16}$ in. (1·58 mm.) | $\frac{1}{16}$ in. | Diamond | 2·5 mm. |
| Proportional load | 5·9 D² | 10 D² (a) | 19·8 D² | 39·7 D² | 59·5 D² | Cone | 30 D² (a) |
| Rockwell's designation | A | — | — | B | — | C | — |
| Full designation showing ball and load used | B $\frac{1}{8}$ in./60 | C 2·5/62·5 | B $\frac{1}{8}$ in./100 | B $\frac{1}{16}$ in./100 | C $\frac{1}{16}$ in./150 | C | C 2·5/187·5 |

(a) Accepted Brinell load. (b) Normal Rockwell test. (c) Special Rockwell test.

TABLE II.

Brinell, Rockwell, and Scleroscope Hardness of Various Metals.

| — | $H_{2\cdot5}D^2$ | $H_5D^2$ | $H_{10}D^2$ | $H_{2\cdot5/62\cdot5}$ | (3) $B_{\frac{1}{16}''/100}$ | (3) $C_{2\cdot5/62\cdot5}$ | (1) Hs | (2) $\sigma_{0\cdot2}$ |
|---|---|---|---|---|---|---|---|---|
| Copper annealed | 38·4 | 44·0 | 47·5 | 51 | -30 | 35 | 11 | 7 |
| 5% cold rolled | 58·0 | 62·0 | 65·1 | 66 | 12 | 58 | 15 | 14 |
| 10% cold rolled | 68·0 | 73·2 | 74·8 | 75 | 33 | 63 | 16 | 20·5 |
| 20% cold rolled | — | 89·2 | 88·3 | 91 | 47 | 69 | 19 | 28 |
| 40% cold rolled | — | 96·0 | 96·7 | 97 | 53 | 72 | 22 | 32 |
| 60% cold rolled | — | 104·0 | 101·0 | 102 | 64 | 74 | 26 | — |
| 85/15 brass annealed | 54·0 | 59·0 | 64·0 | 69 | 19 | 56 | 13 | 11 |
| 5% cold rolled | — | 90·6 | 93·0 | 92 | 52 | 68 | 19 | 26·5 |
| 10% cold rolled | — | 100·0 | 103·0 | 103 | 62 | 72 | 22 | 31·5 |
| 20% cold rolled | — | — | 125·0 | 125 | 73 | 76 | 27 | 37·5 |
| 40% cold rolled | — | — | 146·0 | 146 | 82 | 80 | 32 | 45·5 |
| 60% cold rolled | — | — | 161·0 | 164 | 90 | 81 | 36 | 52 |
| 80% cold rolled | — | — | 177·0 | 176 | 91 | 86 | — | — |
| 62/38 brass annealed | 49·4 | 55·2 | 61·0 | 62 | 10 | 50 | 14 | 9·5 |
| 5% cold rolled | 73·8 | 78·4 | 84·0 | 84 | 46 | 66 | 18·5 | 19 |
| 10% cold rolled | — | — | 98·0 | 95 | 56 | 70 | 22 | 24·5 |
| 20% cold rolled | — | — | 116·0 | 114 | 68 | 74 | 28 | 32·5 |
| 40% cold rolled | — | — | 153·0 | 155 | 85 | 81 | 36 | 48·0 |
| 60% cold rolled | — | — | 171·0 | 166 | 88 | 83 | 40 | 57·0 |
| 80% cold rolled | — | — | 185·0 | 183 | 91 | 86 | 45 | — |
| 60/40 brass annealed | 62·0 | 69·3 | 77·0 | 80 | 39 | 62 | 16 | 12·5 |
| 5% cold rolled | 78·5 | 85·8 | 91·0 | 87 | 49 | 67 | 19 | 19·5 |
| 10% cold rolled | — | 109·0 | 109·0 | 100 | 61 | 72 | 23 | 26·5 |
| 20% cold rolled | — | 129·0 | 127·0 | 122 | 76 | 77 | 29 | 34·0 |
| 40% cold rolled | — | — | 159·0 | 148 | 86 | 80 | 34 | 47·0 |
| 60% cold rolled | — | — | 174·0 | 170 | 93 | 84 | 48 | 58·0 |
| 80% cold rolled | — | — | 186·0 | 185 | 95 | 86 | — | — |
| Aluminium annealed | 23·0 | 23·8 | 23·9 | 27·6 | — | -10 | 7·5 | 4·3 |
| 5% cold rolled | 26·2 | 26·6 | 26·4 | — | — | — | — | 7·3 |
| 10% cold rolled | 31·0 | 31·0 | 29·7 | 29 | — | 4 | 8 | 10·0 |
| 20% cold rolled | 34·6 | 34·4 | 31·8 | 33·4 | — | 20 | 10 | 10·4 |
| 40% cold rolled | 38·3 | 39·2 | 35·5 | 36·2 | — | 26 | 10·5 | 13·0 |
| 60% cold rolled | 42·8 | 42·6 | 40·2 | 40·0 | -44 | 35 | — | 14·5 |
| 80% cold rolled | 44·2 | 43·6 | 41·9 | — | — | — | — | — |
| Scleron tempered | — | — | 135 | 130 | 79 | 78 | 34 | 30·5 |
| 10% cold rolled | — | — | 147 | 130 | 79 | 78 | 37 | 34·0 |
| 20% cold rolled | — | — | 143 | 140 | 81 | 78 | 35 | 43·0 |
| Duralumin annealed | — | — | 68 | 65 | 6 | 60 | 17 | 16·5 |
| 5% cold rolled | — | — | 68·1 | 65 | 10 | 60 | 18 | 22·5 |
| 10% cold rolled | — | — | — | 83 | 39 | 67 | — | 24·0 |

(1) Determined with self-registering scleroscope, Model D. Mean of five tests.
(2) Mean value from test-pieces cut with and across direction of rolling.
(3) Mean of five determinations.

For Rockwell hardness B – $\frac{1}{16}$ in./100 and Brinell hardnesses from 50 to 180 (Fig. 2) the equation is—

$$H_{10}D^2 = \frac{8300}{140 - B\ \frac{1}{16}/100} \qquad (1)$$

and for Rockwell hardness C, 2·5/62·5, and Brinell hardnesses from 30 to 180 (Fig 3) it is—

$$H_{10}D^2 = \frac{2900}{100 - C\ 2\cdot5/62\cdot5} \qquad (2)$$

reason it is not to be recommended that the standard load as used for Brinell tests on a particular metal should be used for the Rockwell tests

The curves also show that with increasing hardness the difference in the Brinell hardness numbers is considerably greater than that in the Rockwell hardness numbers, and that only where the tangent from the zero point touches the curve is the percentage increase in the two the same. Differentiation of Eq. 1 explains this. If

for simplicity, the Brinell hardness be represented by HB, and the Rockwell hardness by HR, we get—

$$\frac{d\mathrm{H_B}}{d\mathrm{H_R}} = \frac{8{,}300}{(140 - \mathrm{H_R})^2}$$

or, disregarding the sign, which is of no consequence to the practical evaluation, we have as the final equation—

$$\frac{d\mathrm{H_B}}{d\mathrm{H_R}} = \frac{d\mathrm{H_R}}{140 - \mathrm{H_R}} \qquad (3)$$

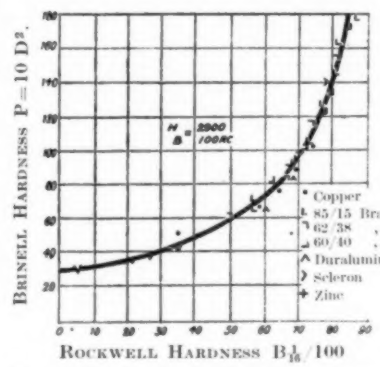



*Fig. 2. Comparison of Brinell and Rockwell Hardness (B1/16/100).*

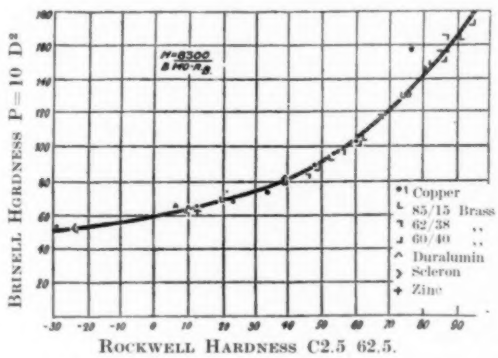



*Fig. 3. Comparison of Brinell and Rockwell Hardness (C2.5/62.5).*

The percentage difference in the two hardness numbers per Rockwell unit is given in Table III. The differences are given for one Rockwell hardness unit, as this is the degree of accuracy, up and down, with which the Rockwell hardness can be determined. As an example, take two materials with Rockwell hardness (B1/16/100) of 10 and 20 respectively; as regards their Rockwell hardness these differ by 100%, so that the one appears to be twice as hard as the other, whilst as regards their Brinell hardness, and therefore their actual resistance to deformation, the difference is only about 8%.[6] From this it is obvious that the full significance of the Rockwell test is only realised when its connection with Brinell hardness is established.

With soft metals of Brinell hardness below 50, difficulties are experienced with the Rockwell test, as there is still a strong flow after the normal period of 5 to 15 secs., so that at the moment of reading the hardness the depth gauge has not yet come to rest. For such metals the period during which the load acts must be so long that a stable condition is reached, or at least so long that during the lifting off of the main load no change in hardness exceeding the irregularities of the material can take place.

## Drawn Metal.

The above relations were determined on rolled test-pieces. This raises the question of whether they can also be used for drawn test-pieces, a question which can only be answered conditionally in the affirmative, as the hardness of a drawn rod is not regular over the whole cross-section.[7]

The hardness is greatest in the edge films, and falls off towards the centre. This is of especial significance where Rockwell tests are concerned, as the area affected by the impression is smaller. For this reason differences are obtained when Brinell and Rockwell hardnesses are taken at the same distance from the centre of cross-section of the test-rod, or on the filed outer surface. Also, the Brinell hardness is affected by the size of the ball used (Table IV.). The hardness of the edge films can be determined on the surface of the cylinder with a reasonable approximation by the Rockwell test (Fig. 4). The difference in hardness over the cross-section amounts to 40%. As far as could be ascertained, the hardness in the direction of the axis at the centre of cross-section and perpendicular thereto was the same.

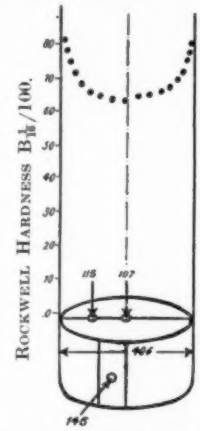



*Fig. 4. Brinell and Rockwell Hardness of Drawn Rod.*

## Scleroscope Hardness.

Shore's rebound hardness test is basically different from the Brinell and Rockwell tests. Whereas in the latter only the residual deformation of the material is taken into account in estimating the hardness, with the scleroscope the hardness is based on the "spring" of the material, since the rebound of the dropped hammer can only be due to elastic forces existing in the material under test. As, however, the energy remaining in the hammer on the

TABLE III.

PERCENTAGE ALTERATION IN ROCKWELL AND BRINELL HARDNESS PER ROCKWELL UNIT.*

| When the Rockwell hardness B 1/16/100 is.. | 1 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| % alteration in Rockwell hardness per Rockwell unit .................. | 100 | 10 | 5 | 3·4 | 2·5 | 2·0 | 1·7 | 1·4 | 1·25 | 1·1 | 1·0 |
| % alteration in Brinell hardness per Rockwell unit .................. | 0·7 | 0·77 | 0·8 | 0·9 | 1·0 | 1·1 | 1·2 | 1·4 | 1·7 | 2·0 | 2·5 |

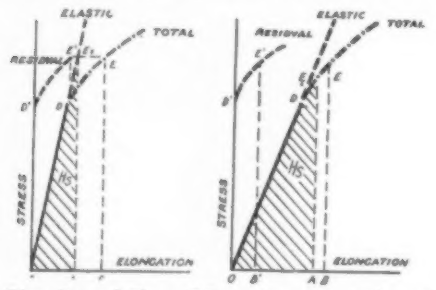
* 1 Rockwell unit on the scale 0—100 (Fig. 1) corresponds to a movement of 0·002 mm. in the test-point.

TABLE IV.

DEPENDENCE OF BRINELL HARDNESS OF DRAWN (BRASS) RODS ON POSITION OF IMPRESSION.

| Diameter. Mm. | Centre of Cross-section. | | At Distance ¼ D from Edge. | | On Filed Outer Surface. | | Maximum Difference, %. |
|---|---|---|---|---|---|---|---|
| | HB 5/250 | HB 10/1000 | HB 5/250 | HB 10/1000 | HB 5/250 | HB 10/1000 | |
| 40 | 107 | 112 | 115 | 112 | 146 | 143 | 34 |
| 30 | 107 | 111 | 106 | 111 | 150 | 144 | 36 |
| 20 | 119 | 124 | 123 | 124 | 142 | 137 | 20 |

rebound is so chosen that it is always greater than can be absorbed by the limited impact position purely elastically (with hardened steel the rebound is 100 to 140), a portion of the work due to the drop is converted to plastic work, the amount being the greater the lower the elastic work the test-piece can absorb. The elastic work absorbed is dependent on the elastic limit and the modulus of elasticity.




*Figs. 5a and 5b. Schematic representation of stress conditions in two materials with different moduli of elasticity.*

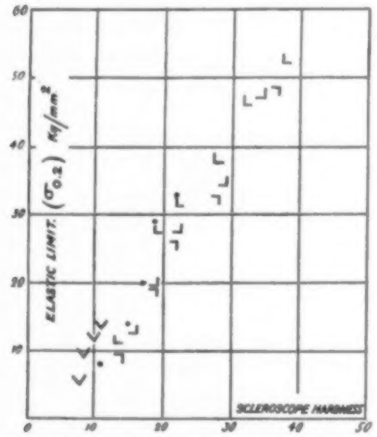



*Fig. 6. Connection between Elastic Limit and Scleroscope Hardness.*

modulus of elasticity of about $0{\cdot}5 \times 10^{-6}$, and copper and its alloys with a modulus of elasticity of about $1{\cdot}4 \times 10^{-6}$.

In the most general case the scleroscope hardness is characterised by the product of the elastic limit and the modulus of elasticity, the capacity for strengthening also influencing it. This is most clearly shown by the fact that vulcanised rubber has about the same scleroscope hardness as hard steel.

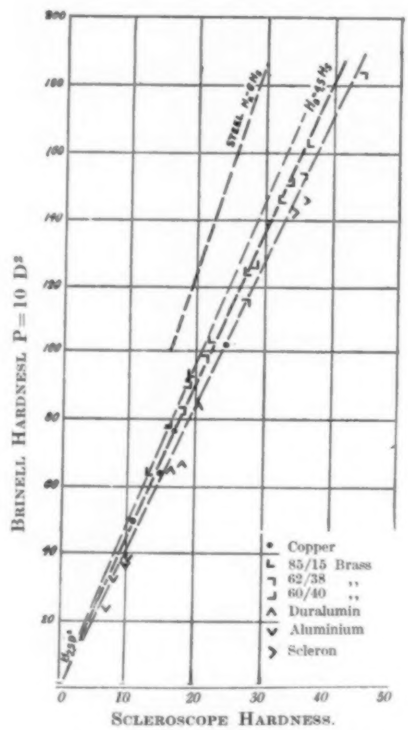



*Fig. 7. Connection between Brinell and Scleroscope Hardness.*

Within the above-mentioned groups it is to be expected that there would be some relation between the scleroscope hardness and the elastic limit. As Fig. 6 shows, this is not quite the case, at least not to the extent that a practically useful relation can be deduced. This must be due in part to the size of the residual impression. With the Brinell hardness a better relationship exists. From Fig. 7 the following expression, which gives a deviation of about $\pm 5\%$ is obtained for non-ferrous metals—

$$H\ 10\ D^2 = 4{\cdot}5\ Hs$$

For steel the accepted expression is $H_N = 6$ Hs, and it is obvious that the lower conversion figure for non-ferrous metals is due to the higher modulus of elasticity. This is also borne out by the fact that in Fig. 7 the experimental points for the aluminium alloys lie away from the line corresponding to this expression.

The practically linear relation between Brinell and scleroscope hardness points to a certain advantage of the scleroscope, as compared with the Rockwell, hardness, since the difference between Brinell and scleroscope hardness numbers is always in the same proportion, only the order of magnitude being different. Despite this, the scleroscope hardness test for metals has not attained the importance which to-day attaches to the Rockwell test.

Figs. 5A and 5B show schematically what happens with a simple state of stress in the case of two materials which are absolutely alike in mechanical behaviour and differ only as regards modulus of elasticity. The work of the hammer is absorbed elastically up to the elastic limit, and the residue is converted into residual deformation work. Owing to the strengthening effect the elastic limit rises from D to E, and the shaded portion gives a measure of the stored-up energy of the "spring" and consequently a measure of the rebound. The surface O D E¹B¹ (Fig. 5B) forms a measure of the residual impression. It is obvious that under otherwise similar conditions the material with the higher modulus of elasticity will give the greater rebound hardness. It follows, therefore, that, strictly, only materials with the same modulus of elasticity can be compared on the basis of scleroscope hardness. A distinction must, therefore, be made between the groups, iron, steel, and nickel, with a

1 Cf. *Z.f. Metallk.*, vol. 21 (1929), p. 387; vol. 22 (1930), p. 175.

2 See Deutsch and Fiek on the Rockwell hardness tester, *Z.d. V.D.I.*, vol. 72 (1928), p. 1541. Cf. also Sheet B 8 of the Werkstoffhandbuch Nichteksenmetalle.

3 Technical Paper, Bureau of Standards, No. 334, Wzshington, 1927.

4 *Maschinenbau*, vol. 8 (1929), p. 69.

5 Schwarz, Zugfestigkeit und Hårte bei Metallen, Forschungsarbeit auf dem Gebiet des Ingenieurswesens, No. 313; Cf., *Z.f. Metallk.*, vol. 21 (1929), p. 128. See also Wallichs and Schallbach, Maschinenban, vol. 8 (1929), p. 824.

6 In scientific investigations this permits of quite small differences being determined, rovided that the same edge "roll" effect occurs in both the samples being compared.

7 The greater hardness at the edge is due to the stronger flow of the edge films on drawing. This also gives rise to internal stresses which, according to the author's investigations, may almost reach the elastic limit in the outside skin. By suitable treatment these stresses may be removed, with practically no effect on the greater hardness of the skin or on the hardness as a whole.

## Catalogues and Other Publications.

Samuel Fox and Co., Ltd., Stocksbridge Works, Sheffield, have issued a brochure dealing with road vehicle springs. It includes interesting information concerning the design, materials, and manufacture of springs for all types of road vehicles, and many types of spring are illustrated. This brochure may be obtained on application to the firm at the above address.

In addition the the usual pages of abstracts and general references, the December issue of the *Nickel Bulletin* contains a description of the Mond process of refining nickel, as used at the Clydach Refinery of the Mond Nickel Company, and also an interesting article on De Havilland Gipsy Aero Engines, and the extensive use of nickel alloys in their construction. This bulletin, and also a very complete and well-illustrated publication dealing with the properties and practical application of Nickel cast-iron, may be obtained on application to the Bureau of Information on Nickel, the Mond Nickel Company Limited, Imperial Chemical House, Millbank, London, S.W. 1.

Messrs. Brown Bayley's Steelworks, Ltd., have sent us a number of leaflets dealing with their products, which include many kinds of stainless steel equipment for chemical plant and laboratory use, as well as the actual plates, sheets and sections for the construction of the plant. These latter are chiefly constructed of "Brearley K" Brand Stainless Iron which is a corrosion-resisting steel suitable for nitric acid storage tanks and reaction vessels. These leaflets may be obtained from the company's works at Sheffield.

# Recent Developments in Tools and Equipment

## Pulverised Fuel Firing.

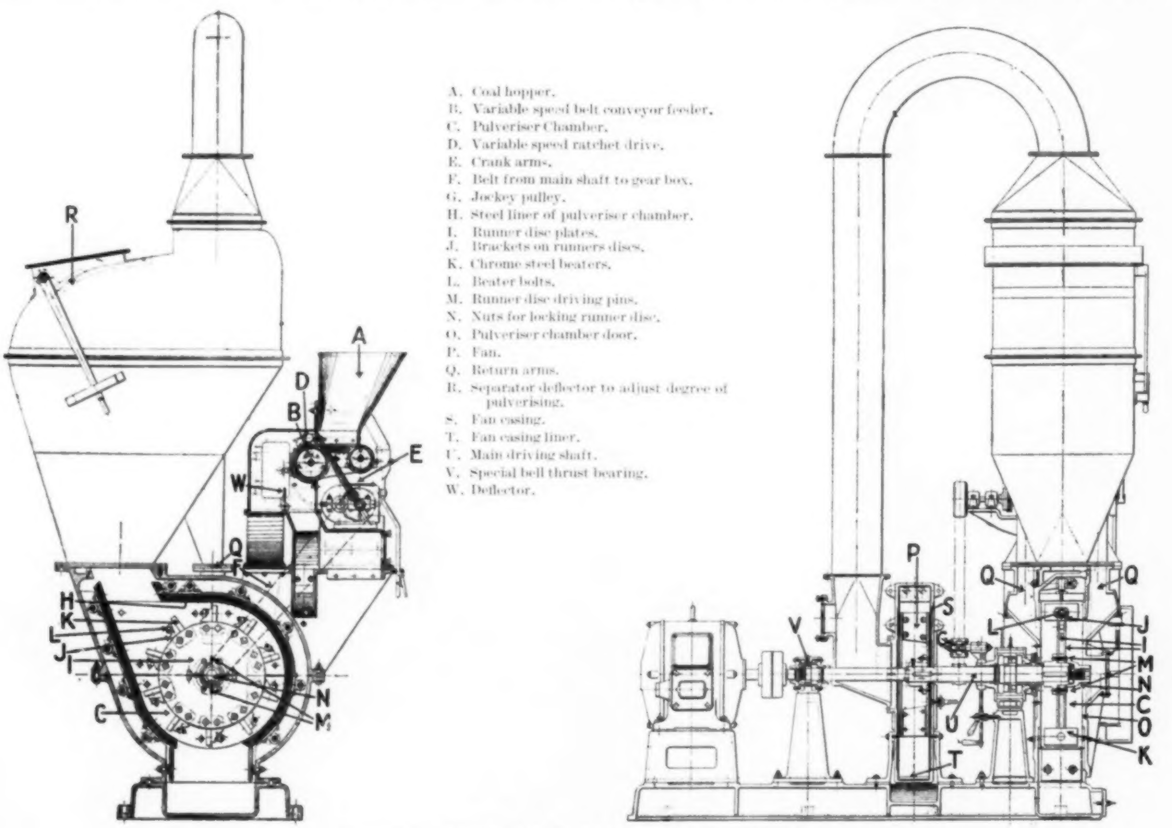
### Latest Developments in the "Unit" System.

IMPORTANT for the iron and steel and general metallurgical industries is the advance, especially in the past two years, in "unit" type of pulverisers for steam boilers, in competition both with the "bin and feeder" system and mechanical stoking. Obviously, the principle of a compact, self-contained pulveriser has a number of attractions, alike for cylindrical and water-tube boilers on land and sea, and general furnace applications in the metallurgical, cement, glass, and many other industries. The progress being made is strikingly illustrated by the contracts that have just recently been placed for the first section of the new "Dunston B" station of the Newcastle-on-Tyne Electric Supply Co., Ltd. The equipment is to include 12 water-tube boilers, of which 6 are "Babcock and Wilcox," combined steam generators and reheaters, each of 125,000 lb. per hour normal evaporation, with 625 lb. pressure and 825° F. superheated steam temperature, while also raising 200,000 lb. of steam per hour at 150 lb. pressure from 520° to 825° F. The other 6 boilers are "Clarke, Chapman" make, with normal evaporation of 156,000 lb. per hour, each at 625 lb. pressure and 825° F. as before; 8 of the units are to be mechanical-stoker fired and 4 pulverised-fuel fired, and three 50,000 k.w. turbo-generators are to be built by Charles Parsons and Co., Ltd.

The station has a number of outstanding features, including moderate pressure, high superheating, and extensive use of reheating, but special interest attaches to the pulverised-fuel firing equipment to be fixed on four of the boilers, which is of the "Resolutor" unit type, by Clarke, Chapman and Co., Ltd., of Gateshead-on-Tyne, their complete contract being £235,000.

For the four boilers there will be eight standard pulverisers, each of 5 tons of coal per hour capacity, 8–15% moisture, grinding down equivalent to 75–80% through 200-mesh screen—that is, 10 tons of coal per boiler per hour, with two machines and two burners.

In this latest design of unit pulveriser, damp coal of 15–20% moisture content, or even over, is taken direct, without difficulty, from the small feed hopper at the top, being delivered to the pulverising chamber, adjustable in amount as desired, by a short, horizontal variable speed belt conveyer, operated by a ratchet drive, with gearbox and belt from the main shaft. The pulveriser chamber is of semi-steel, lined inside with a series of hard chrome-steel liners, which are easily removed, and inside the chamber is a high-speed runner or pulveriser disc made of two mild-steel plates bracketed together, each bracket carrying renewable chrome-steel beaters, secured by high-tensile steel bolts. This composite pulveriser disc is secured to a horizontal heavy steel main shaft, having dust-tight roller bearings, by driving pins and a locknut, and runs at about 1,500 r.p.m., the coal being immediately disintegrated by the high-speed beaters. Also, the particles are automatically separated on the gravity principle by a current of very hot air entering the pulveriser from the boiler furnace, and passing up into an air-separating chamber above



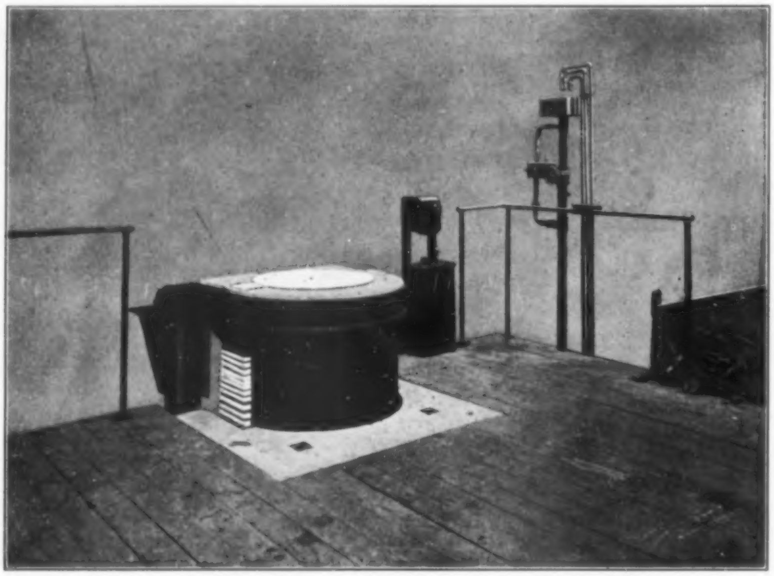

*Elevations showing the Resolutor unit type pulveriser.*

the pulveriser chamber. From the top of this chamber, the stream of heated air and separated pulverised coal passes down by a trunking to a fan, also on the main shaft, which is driven at one end by a direct-coupled motor on the same baseplate with flexible coupling. From this fan, the pulverised coal, with about 25% of the air for combustion, is delivered to the burner operating on the "turbulent" principle, fixed in front of the combustion chamber. The particles of coal that are not sufficiently fine drop back by gravity into the pulveriser chamber, and the degree of grinding is controlled, on the most ingenious lines, by an adjustable separator deflector, which impedes the rapid flow of air particles to a more or less degree, so as to alter the proportion of coal of a certain size that falls back into the pulveriser.

Individual "Resolutor" self-contained units can now be supplied up to 10 tons of coal per hour capacity, and the design is particularly valuable for the use of lower-grade coals in the mining areas, since pre-drying, as stated, is not necessary, and tramp iron causes no damage because of the ample clearance between the runner and the casing, merely falling out into a recess at the bottom of the casing.

## The Stobie High-frequency Induction Furnace.

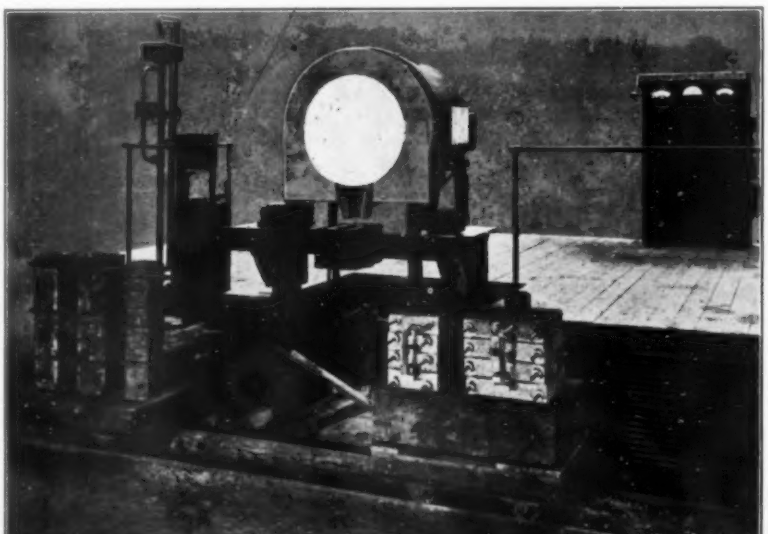
WHILE the advent of the electric-arc furnace had a considerable influence on the old-type crucible it was hoped to supplant, it was generally considered that the intense heat developed by the arc had many disadvantages in melting plain-carbon crucible steels. During recent years, however, the crucible process has been developed in a different way, by making use of electricity, and has resulted in the high-frequency induction furnace now so well known. A recent development of this type of electric melting plant is the Stobie high-frequency induction furnace. On reference to the accompanying illustrations it will be noted that this furnace follows the well-established steelworks practice of having a clear platform around the furnace and, in this respect, differs from some furnaces of this type, which have their tilting gear above the platform. In this new design every effort has been made to clear the platform of any mechanism likely to impede or endanger the operator. Of all the types of furnaces employed in the production of steel none is easier to manipulate than this type, and it is of particular interest that, in small furnaces, steel is produced in crucibles at no higher cost than ordinary steel in melting plant of much larger capacity. With this type of plant in a foundry, for instance, there is no need to compromise with an average carbon content of the steel for a variety of castings, as each small batch of castings can, if required, be made to any special analysis.



*7-cwt. Stobie High-frequency Induction Furnace.*

The cost of operating a high-frequency furnace is unexpectedly low. As a rule the current consumption is somewhat less than in an arc furnace in proportion to metal melted; the labour involved can be conveniently managed by the furnace operator with the occasional help of a handy man; the refractory and other costs are somewhat similar to those incurred in arc furnaces; and, in a well-designed installation, maintenance is almost negligible. With an installation of this type a steel foundry possesses an equipment which favours production at relatively low cost, deliveries of molten steel every hour, any composition of steel desired, control that gives the steel perfect condition in the fluid state, and provides an easy method of steel-making.

The potentialities of this type of steel-melting equipment are very considerable, and new avenues of application will be developed as its possibilities become more widely known and appreciated. At the moment it has a wide field of utility in the modern steel foundry, but, in the future, its usefulness will undoubtedly be extended, with a view to the reduction of difficulties associated with the production of costly alloy steels.



*Showing the same Furnace in a tilted position.*

# Some Recent Inventions.

## RENDERING AUSTENITIC NICKEL-CHROMIUM STEELS NON-CORRODIBLE.

It has long been recognised that a polished surface on certain metals gives greater corrosion-resisting properties to the metal than a surface not highly polished, and this property is considered to be due to the procedure adopted in preparing the surface, resulting in the formation of a protective or passive surface. Tests have proved that the corrosion resistance which occurs in the surface of metals of identical composition is variable, due to lack of uniformity in such passive surface.

A new process has been devised, the object of which is to provide a method by which a consistently passive surface may be produced. In this process the metal, after being prepared to produce the kind of surface desired, whether rough or polished, is subjected to heat-treatment, but at such a temperature—ranging from 100°—400° C.—that oxidation effects are not apparent. The length of time during which an article is subjected to heat-treatment and the temperature employed are variable and depend upon the nature of the article. Thus, for instance, the higher the temperature the shorter will be the duration of treatment. After heat-treatment any convenient method of cooling may be employed. By the adoption of this process a passive or corrosion-resisting surface can be produced which will give a very high and uniform resistance to the corrosive action of various corroding media, and is particularly applicable to the manufacture of plant and apparatus for use in chemical work as well as for other plant and apparatus where a surface is required to be resistant to corrosive action.

The range of corroding media which a steel will resist varies with the composition of the steel, but all austenitic nickel-chromium steels containing 10% to 25% of chromium and 25% to 5% of nickel, have a considerable but varying range of corroding media which they will resist. This resistance is, however, still subject to limitations, and, as an example, a stainless steel of the composition, carbon 0·14%, nickel 8·0%, chromium 18·0%, shows corrosion when treated with citric acid solution, but after treatment at 200° C., according to the present invention it then gives uniform resistance to citric acid. Similarly, other austenitic chromium-nickel stainless steels have their resistance to corrosion increased by this process of heat-treatment, and these include steels containing any one or more of the following elements: Molybdenum, tungsten, or copper, aluminium, zirconium, vanadium, and titanium. For example, if 2 or 3% of molybdenum or 0·5 to 1·5% of tungsten, or 3·0% of copper, be added to these alloys, the range of resistance to corroding media is increased by heating in the manner referred to.

333,237. Dr. W. H. Hatfield, of Sheffield, and Harry Green, Secretary to Thos. Firth and Sons, Ltd., of Sheffield, patentees. Messrs. Mewburn, Ellis and Co., agents, 70-72, Chancery Lane, London, W.C. 2.

## IMPROVEMENTS TO CUPOLA FURNACES.

Although various designs have been proposed from time to time with the object of improving efficiency and economy, the standard cupola in use to-day retains the simplicity of early designs in all essential features. Increased economy and improved efficiency have been obtained primarily as a result of modifications in dimensional relationship of the various parts, but also as a result of improvements in the methods of storing and charging of pig iron and scrap and improved arrangements for distributing the fluid metal. Modifications in dimensional relationship have received considerable attention from foundrymen, metallurgists, and engineers, particularly in regard to the shape and proportions of the internal form of the cupola, the area and number of tuyères, pressure volume and velocity of the air supply. During recent years much progress has been made in the development of the soft blast. A recent improvement in design of what is known as a balanced blast type of cupola promises for the first time to provide a cupola furnace that is controllable. The improvement relates to those cupolas having supplementary rows of tuyères above the main tuyères situated adjacent the melting zone. In such cupolas it is customary to provide regulating valves in combination with the supplementary tuyères and much difficulty has been experienced in obtaining proper regulation of the air to the different parts of the cupola; it has, in fact, been found impossible by regulation of the supplementary tuyères to obtain the best control and distribution of the air required for the most efficient operation of the cupola. The object of this recent improvement is to overcome this difficulty in a simple and convenient manner. It consists in a method of proportioning the amount of air supplied from a common source to the main and supplementary tuyères of cupolas, and is characterised by the feature that the air supply is controlled at the main tuyères only.

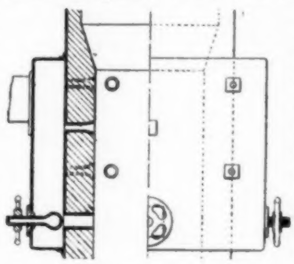


*Fig. 1.*

The principle employed is to control the main tuyères by means of screw valves in such a way that air can be throttled independently at each tuyère, as shown in Fig. 1. A hollow spherical valve is arranged opposite the outer end of each tuyère, which is formed with a screwed hollow stem capable of being rotated by a handle outside the wind belt. Apertures at opposite ends of each stem enable the interior of the cupola to be inspected. In the same wind belt are two or more rows of small tuyères, and the closing of the main tuyères automatically results in more air passing through the upper tuyères. In this way the varying requirements set up by changes in the coke supply, in the size of scrap, nature of iron melted, and other conditions can be provided for by very rapid adjustment. The results of working experience on a cupola, with this modification in design, are claimed to have fully justified the anticipations from the original test results. The advantages appear to be increased output per hour, considerable economy in coke, reduction in expenditure incurred in patching and repairs to the lining, and a reduction in residue.

333,322. J. E. Fletcher and the British Cast Iron Research Association, patentees. August 14, 1930.

## TUNGSTEN INGOTS.

In making tungsten ingots by the dry process, in which tungsten powder is compressed and sintered, freedom from residual oxygen is assured by intimately mixing the powder with a more volatile metal, such as silver, compacting the mixture and then sintering and volatilising all the added metal, leaving an unworked pure tungsten ingot.

The product is suitable for making filaments, spark points, make-and-break contacts, etc. The mixture to be compacted may be formed by reducing with hydrogen an intimate mixture of tungstic oxide and a reducible silver oxide chloride; or solutions of silver nitrate and sodium tungstate may be added simultaneously to dilute hydrochloric acid, and the mixed precipitate may be reduced; or silver nitrate solution may be added to sodium tungstate solution, and the precipitate treated with hydrochloric acid. The product may be made to contain over 1·5% of thoria, and in such case a mixture of tungsten, silver, and thoria is compacted, and sintered at such a temperature as to volatilise the silver and sinter the tungsten, and the resulting ingot is swaged and drawn; or thorium nitrate may be added to the mixture of tungstic oxide and silver chloride prior to reduction by hydrogen. The amount of silver added may be about equal to the thoria content, and may be about 0·5—10% of the tungsten.

337,160. A. Pacz, of Frankfort-on-Main, Germany, patentee. J. Gray, agent, Aldwych, London.

## England's Largest Blast Furnace.

The first blast furnace to be built in the south of England is rising rapidly on the site of the new Ford works at Dagenham. It is designed to produce 500 tons of pig iron per day and, to maintain this average, 2,000 tons of coal, ore, and limestone will be necessary. While the blast furnace is now almost completed, the work on the 45 ovens forming the coke-oven block is also well advanced. These ovens are designed to convert 800 tons of coal per day and, by means of a special installation, steam will be generated from the coke for use in other sections of the works. In order to cope with the large quantity of coal and coke, work is proceeding on a special installation for handling these materials. This coal-handling plant will operate almost automatically, and will select and grade the various sizes of coke produced in the ovens. Situated adjacent the ovens will be the by-products section, where liquid residues produced in the coke ovens will be treated and the derivatives converted into marketable forms.

The manner in which this site, which formerly comprised a large area of apparently useless marsh land, is being converted into an enormous works is little short of marvellous, and is a noteworthy achievement for the architects, manufacturers, and contractors who are responsible for the work involved in the various buildings and installations.

There is still much work to be done before the factory will operate on a production basis, but the whole area within a reasonable distance of this embryo factory is developing fast; dwelling houses, shops, roads, etc., have changed the whole character of the district. When the factory is completed, and production is in full swing, about 15,000 workers will be employed. Thus, in addition to the marshy land, Dagenham itself is being transformed.

## Japanese Steel Amalgamation.

In order to preserve their position in regard to China and other Eastern markets, Japanese steelmakers, at the instigation of their Government, have recently adopted a far-reaching plan. This consists of an arrangement whereby the Japanese State iron and steel works at Yawata will amalgamate with all the private steel companies of Japan. The new combination will be capitalised at the equivalent of £60,000,000.

The scheme includes proposals for controlling steel imports into Japan, for establishing stockyards at points in China, and for centralisation of the banking business required in financing steel production. Apparently the Japanese are organising to challenge the British and American steel firms in Eastern markets.

## Germany Imports More British Coal.

It is not surprising that anxiety is being expressed in Germany regarding imports of British coal, which amounted to 5,200,000 tons in the first nine months of 1930, compared with 5,400,000 tons in the whole of 1929. For the whole year 1930 it is expected that imports of British coal will reach about 7,000,000 tons. It is imported in particular by German gasworks; for instance, fourteen gasworks increased their consumption of British coal during the two years from 1927 to 1929 by 36.4 per cent., while their consumption of German coal declined 2.27 per cent. Even in the heart of the German coal industry, at Duisburg and Dortmund, British coal is competing with German. British competition is also keenly felt by Germany in countries favourably situated for Great Britain from the point of view of freights. The German coal industry is also being subjected to competition from the West, and the Polish mines are also endeavouring to participate in all business. As a result of this keener competition it is becoming more and more difficult for the Ruhr Coal Syndicate to maintain the position it has gained on the export market.

## Motor Ship Construction.

The remarkable progress in the development of motor vessels is indicated by the increase in construction. During 1930 the number of large vessels of this type built throughout the world was 240, totalling 1,640,000 tons gross, which is 40 per cent. more than has been recorded in any previous year. It is interesting to note that the proportion of this motor ship tonnage built in this country was 45 per cent., compared with 37 per cent. a year ago, the actual total amounting to 747,000 tons gross, of which 280,000 tons gross were for foreign owners.

The outlook for the coming year, although much less satisfactory than at the beginning of 1930, is not wholly unfavourable, for there are more than 280 motor ships on order throughout the world.

## Japan as a Competitor in Steel Work.

A further development in the increased competition for steel contracts is provided by the success of a Japanese firm in securing the contract for the building of a railway bridge in Siam. The contract has been obtained in spite of European and American competition, and the success of this firm indicates possibilities in a field of enterprise in which Japan has previously been unable to enter. Although the value of this contract is comparatively small—60,000 yen (£6,000)—it was secured by an elaborate scheme of co-operation. The Government railway engineer prepared the design, and the cost was fixed in consultation between Government and private steel works, the shipping line concerned, the Japanese Federation of Bridge Constructors, and the great trading firm of Mitsui. It is admitted that the price does not allow of any profit, but Mr. Egi, Minister of Railways, declares that the development of a foreign market for Japan's engineering industry means more to the nation than immediate gain.

Japan recently lent railway experts to Persia and Russia, and it is hoped that the Siamese success will open the way to contracts from those two countries.

## Steel Manufacturers Revise Rebates.

The decision of the members of the National Federation of Iron and Steel Manufacturers to increase the rebates they offer those firms signing an undertaking to use only British steel, instead of reducing their prices, was not unexpected. With one exception, this leaves the price of structural material unaltered, as well as the plate prices. The official quotation for joists, however, has been advanced 5s., but this has been made good to firms in the rebate scheme by an increase in the allowance of 10s.

The steelmakers' decision will meet with some criticism, as quite a number of merchant and engineering firms, particularly in London and the South, protest that the nature of their business makes it imperative for them to buy a certain amount of Continental steel. They claim that the steelmakers, by their rebate scheme, force them to buy larger quantities of foreign steel than they otherwise would. On the other hand, steelmakers are satisfied with the effect of their scheme since it was put into operation, and claim that all North of England shipbuilding firms are parties to it.

## Iron and Steel Production Reduced.

During December the number of furnaces in blast fell to seventy-six. Of the sixteen furnaces which ceased operations, eleven were damped down. Production of pig-iron in December amounted to 349,800 tons, compared with 384,100 tons in November and 643,000 tons in December, 1929. The production includes 91,400 tons of hematite, 122,700 tons of basic, 105,300 tons of foundry, and 18,300 tons of forge pig-iron. The December output of steel ingots and castings amounted to 337,200 tons, compared with 433,800 tons in November and 661,200 tons in December, 1929. The total production of pig-iron for the year amounts to 6,300,000 tons, and of steel to 7,600,000 tons, compared with 7,589,300 tons and 9,636,200 tons respectively in 1929.

## Staveley Directors Honoured.

Sir William Bird and Mr. D. H. Turner, chairman and managing director, respectively, of the Staveley Coal and Iron Co., Ltd., were recently made the recipients of engraved and inscribed silver salvers as a token of esteem from the officials of the company. The presentations were made at a dinner given in Chesterfield to 400 officials from the various collieries and the works of the company. Each piece of plate was engraved with colliery headstocks, coke ovens, blast furnaces, and stacks of pipes, illustrating the wide activities with which the company is directly concerned.

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We are informed that the Alloy Welding Processes, Ltd., and the Premier Electric Welding Co., Ltd., have been amalgamated, and the new company, which commenced to operate as from January 1, 1931, is known as Murex Welding Processes, Ltd. The address of offices and works will remain unaltered.

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Mr. G. H. Harrison, of "Haselmere," Knoll Avenue, Swansea, has been appointed by the Power Plant Co., Ltd., West Drayton, Middlesex, as agent for South Wales District.

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An agreement has been entered into between the Whessoe Foundry and Engineering Company, of Darlington, and Arthur K. McKee and Co., of Cleveland, U.S.A., under which the former firm will act as exclusive manufacturing agent in Great Britain and Ireland for the McKee oil refinery and blast furnace equipment.

# Some Contracts.

A contract for the structural steelwork for the new Shell-Mex building in London, has been awarded to Messrs. Dorman, Long and Co., Middlesbrough, who have also secured the following other contracts :—Erection of a new bridge over the River Foyle at Londonderry, at a cost of £255,510 ; erection of the new Tees Bridge at Newport, Middlesbrough, at a cost of £616,000 (this bridge is to be of the vertical lift type (a type unique in this country), and is being built by the Durham County Council and Middlesbrough Town Council, with the assistance of the Government, which is to provide 75% of the cost) ; supply of 10,000 tons of steel for the construction of the new hotel at the Marble Arch, London.

Among other contracts that Messrs. Dorman, Long and Co. have in hand, are :—The Sydney Harbour Bridge (£8,000,000) ; the Scotswold Bridge (£32 000) ; Lambeth Bridge (£500,000 ); Putney Bridge (£433,000) ; Rhyl Bridge (£86,000), and the Memorial Bridge, in Siam.

The Admiralty have decided to entrust the contracts for the new cruisers and destroyers of the 1930 programme to the following firms :—Cruiser, hull and machinery : Messrs. Cammell Laird and Co., Ltd., Birkenhead ; machinery for two cruisers : Messrs. Vickers, Armstrong, Ltd., Barrow-in-Furness, and Messrs. Parsons Marine Steam Turbine Co., Ltd., Wallsend-on-Tyne ; two destroyer hulls and machinery: Messrs. Fairfield Shipbuilding and Engineering Co., Ltd., Govan, Glasgow ; machinery for two destroyers : Messrs. Palmers Shipbuilding and Iron Co., Ltd., Jarrow-on-Tyne ; other machinery for two destroyers : Messrs. J. R. Thornycroft and Co., Southampton ; hulls and machinery for two destroyers : Messrs. Vickers-Armstrong, Ltd., Barrow-in-Furnesss ; machinery for a flotilla leader : Messrs. William Beardmore and Co., Dalmuir, Dumbartonshire.

A later statement issued in regard to the new destroyers indicates that *Defender* and *Diamond* will be built by Vickers-Armstrong, Ltd. ; *Daring* and *Decoy* by Thornycroft and Co., Ltd. ; *Dainty* and *Delight* by Fairfield Shipbuilding and Engineering Co., Ltd ; and *Diana* and *Duchess* by Palmers Shipbuilding and Iron Co., Ltd., Jarrow-on-Tyne.

The Tyne Dock and Engineering Co., Ltd., South Shields, have secured a contract for re-conditioning the steamer *Stork*, belonging to the General Steam Navigation Company, Ltd., London. The contract will provide employment for hundreds of men for five or six weeks.

The Great Western Railway Company has placed the following contracts :—Supply and erection of a movable coal hoist and electrically-operated traverser for Queen Alexandra Dock, Cardiff—Hydraulic Engineering Co., Ltd., Chester. Steel jetty for a new coal conveyor at Roath Dock, Cardiff—Geo. Palmer, Neath. Supply and erection of an electric 30-ton Goliath crane for Morpeth Dock, Birkenhead—Clyde Crane and Engineering Co., Ltd., Mossend, Lanarkshire. Supply and erection of a 20-ton electric Goliath crane, Herbert Street good yard, Wolverhampton—Clyde Crane and Engineering Co., Ltd., Mossend, Lanarkshire. Supply and erection of a three-ton electric capstan, at Glasgow Wharf, Plymouth Dock—Ransomes and Rapier, Ltd., Ipswich. Supply of a steel-framed building at Evesham—J. Tildesley, Ltd., Darlaston, Staffordshire.

The L.N.E.R. Company has placed an order with Messrs. Richard Dunston, Ltd., of Thorne, for three new steel-screw tug-boats, each 60 ft. long by 14 ft. broad, for service at Grimsby docks.

The renewal has been secured of the Blackburn Aircraft Company's contract with the Greek Air Ministry, for the continued supervising of the Government Aircraft Factory at Phalerum for a period of seven years. The company has also received a repeat order from the British Air Ministry for the construction at their Brough Works, of " Ripon " torpedo-carrying planes.

The Great Western Railway Company have placed a contract with Cammell, Laird and Co., Birkenhead, for two cross-Channel steamers for the Fishguard-Rosslare service. The contract specially provides that only South Wales steel shall be used, and it is anticipated that the British (Guest-Keen-Baldwins) Iron and Steel Company will receive large orders for the supply of ship plates from their Cardiff works.

Messrs. Harland and Wolff, Belfast, have issued a statement denying the report that they had obtained a contract for the construction of a twin-screw passenger and cargo carrying motor-ship for the Nelson Line. The matter is only under consideration at present. They have, however, booked an order from Messrs. Andrew Weir and Co., for an oil tanker of about 4,000 tons.

Thomas Ward and Sons, Ltd., Wardonia Works, Sheffield, have been awarded what is stated to be a particularly large contract. It is for the complete equipment of the Irish Free State Army with " Wardonia " patent safety razor holders, and the requisite number of " New Edge " blades. " The contract will give an impetus to the sale of Sheffield articles in the Irish Free State," said Mr. Thos. Ward, the managing director of the company.

The Central Electricity Board have placed the following additional contracts, in connection with the schemes the Board have adopted for different parts of the country : S.W. England and S. Wales—Overhead transmission lines : Calenders Cable and Construction Co., Ltd., London, and W. T. Henley's Telegraph Works Co., Ltd., London. Mid-East England—General meters, transformers : Metropolitan Vickers Electrical Co., Ltd., Manchester. N.W. England—Switchgear : General Electric Co., Ltd., Birmingham, and A. Reyrolle Co., Ltd., Hebburn-on-Tyne. Central England—Switchgear : The British Thomson-Houston Co., Ltd., Rugby. S.E. England—Overhead transmission lines (Thames crossing) ; Callenders Cable and Construction Co., Ltd., London. S.E. England—Switchgear : Ferguson Pailin, Ltd., Manchester. E. England—Switchgear : Metropolitan Vickers Electrical Co., Ltd. ; primary transmission lines : Siemens Brothers and Co., Ltd., Woolwich ; transformers : Fuller Electrical and Manufacturing Co., Ltd., London.

Messrs. Braithwaite and Co. (Engineers), Ltd., London, have secured an order for a pressed-steel tank for the Murree waterworks, Dunga Gate, Punjab, India. The tank, which will be constructed at Newport (Mon.), and shipped within two months, will be the largest pressed-steel tank in the world, for it is to have a capacity of about 3,250,000 gallons, its dimensions being 204 ft. × 160 ft. × 16 ft. deep.

The contract recently secured from the Belgian Government by the Fairey Aviation Company, for 45 " Firefly " machines, has now been followed by a second order for the company's " Fox " type, two-seater, high performance aircraft, to a value of more than £300,000.

The Metropolitan-Cammell Carriage, Waggon and Finance Co., Ltd., of Birmingham, have received an order from the Kenya and Uganda Railway for the supply of 58 covered goods wagons.

The British Thomson-Houston Co., Ltd., Rugby, has been successful in obtaining an important order for two 75,000 k.w. turbo-alternators from the County of London Electric Supply Company for their new Barking Extension, the Consulting Engineers being Messrs. Merz and McLellan, London and Newcastle. These machines are the largest yet ordered in this country.

This company has also been successful in obtaining an important order from the London County Council for two 20,000 k.w. turbo-alternators, complete with feed-pumps, heaters, evaporators and condensing plant. These sets will be installed in the Greenwich Power Station for supplying power to the L.C.C. tramway system.

The London Underground Electric Railway Co., Ltd., have placed three contracts for reconstruction work. That for the main work in connection with the installation of subways and escalators at Hyde Park Corner Station has been awarded to Kinnear Moodie and Co., and those for the reconstruction of Sudbury Town Station, and for the extension work at Hammersmith Station, to John Mowlem and Co., Ltd., Ebury Bridge Road, S.W. 1.

Messrs. John I. Thornycroft and Co., have received from the Overseas Motor Transport Co. (London), an order for 108 omnibuses for service in Cairo. The chassis will be the standard four-cylinder, but with left-hand drive, while the bodies will be of the single-decker type, with special features for Egyptian conditions.

Messrs. Thornycroft and Co. have also received an order from the Cardiff Corporation for six B.C. forward drive single-deck bus chassis.

## COKE FOR BLAST FURNACES.

This is the first report of the Midland Coke Research Committee, which was formed at the instance of Professor R. V. Wheeler, of the Department of Fuel Technology at Sheffield University, with a view to extending the research work on the manufacture and properties of coke which had been in progress at the University for several years, and to discuss standard methods of coke testing. The report is divided into three main sections, the first of which discusses briefly the problems to be studied, and outlines the programme of research to be followed and which is dealt with in the second and third sections.

A study of coke for blast furnace purposes involves two main problems: The specification of the qualities of the cokes found to be most suitable; and the production of cokes to conform with this specification. These problems formed the basis of investigations, and the broad lines on which they were to proceed were agreed upon by a very representative committee, of which individual members supplied cokes of known origin and quality for testing and experiment.

The principal qualities of coke that appear to affect its behaviour in the blast furnace relate to its purity, its hardness, and its combustibility. Except, perhaps, for properties relating to purity the determination of the properties of coke involves the use of empirical tests, each detail of which requires to be carefully standardised. The standardisation of these tests was one of the first duties of the committee. The important properties of coke are its size and structure, its chemical analysis, its bulk, apparent and real density and porosity, its abradability, its impact hardness, and its reactivity with oxygen and carbon dioxide.

During recent years the study and manufacture of the ideal coke for blast-furnace purposes has engaged the attention of many investigators. Works laboratories and research departments, as well as independent workers have been engaged on this subject, with the result that the knowledge as to what is and what is not a suitable coke for the various purposes for which it is required is very considerable, but the conclusions have been somewhat confusing.

Primarily the chemical composition only was regarded as the standard on which to base estimates as to the quality of coke; now, of course, it is recognised that the physical properties of the fuel are as important as the chemical analysis. A considerable part of the report is concerned with these physical properties, as well as chemical analysis, and the information given is very complete. The investigations in this direction have been undertaken with a view to building up a specification for blast-furnace coke. Having arrived at some agreement in regard to its specification, after exhaustive tests, the manufacture of a blast furnace coke to meet this specification becomes of really primary importance. Part 2 of the report deals with this section, in which is outlined the constitution of coal, the separation of bituminous coal into the banded constituents, vitrain, clarain, durain, and fusian, and of these constituents into hydrocarbons, resins, recognisable plant remains and ulmins. The importance of the influence of blinding the coal charge is recognised, and some of the results of investigations are given. The methods of controlling the quality of coke have been based mainly on experimental work carried out during 1926-29 at Sheffield University in conjunction with coke-oven plants and blast furnaces in the Midland area, and are discussed in detail.

The preparation of this valuable report will have involved considerable labour, and Messrs. R. A. Mott and R. V. Wheeler are to be congratulated for the excellent manner in which the work has been compiled. The report is well printed, the numerous illustrations being shown to advantage, and the whole is admirably bound. By R. A. Mott and R. V. Wheeler, and published by the Colliery Guardian Co. Ltd., 30-31, Furnival Street, London, E.C. 4.

## IRON AND STEEL REPORT.

From the point of view of actual business the past month in the iron and steel trades has been a distinctly slack one, the fresh factor in the situation to add to the existing depression being the stoppages at consuming works in consequence of the Christmas and New Year holidays. In many instances works were closed down for an extended period, for the sole reason that order-books were in an unsatisfactory state.

The past month has witnessed interesting price developments in the market for foundry iron, although it is to be regretted that the recent substantial reduction in Cleveland iron quotations will probably tend to bring about a fresh period of price uncertainty after a spell of comparative stability. North-East Coast iron masters at the beginning of January brought pig iron prices down by 5s. a ton, with the twofold object of stimulating export trade in foundry iron and of undermining foreign competition in the British home markets, although, incidentally, the "cut" will also have the effect of bringing Cleveland iron into closer competition with Midland brands in certain parts of the country. Whether or not Midland producing interests will feel called upon to make a corresponding reduction in their selling prices remains to be seen, but there is no doubt that consumers are fully alive to this possibility.

Meanwhile, prior to the North-East Coast move already discussed, the Central Pig Iron Producers' Association, representing mainly blast-furnace interests in the Midland counties, put forward a scheme of rebates, which, they state, has met with a good reception among users. The scheme, which, by the way, in a measure tends to remove the cause for complaint during the last year or two, that the largest users were unable to buy foundry iron on any better terms than the smallest, provides for a graduated scale of rebates according to the tonnage bought and delivered over a period of six months. The scale is as follows: From 1,000 to 1,500 tons, the rebate is 6d. a ton; from 1,500 to 3,000 tons, 9d. a ton; and over 3,000 tons, 1s. a ton.

Pig iron consumption throughout the country is badly in need of stimulating, and of this at the moment there is little sign, although the latest steps taken by makers may eventually make their influence felt. The general position of the foundries is probably no worse than it was in the closing months of 1930, but, on the other hand, it is difficult to point to any practical indication of improvement, and aggregate deliveries from the blast furnaces into consumption remain at a very moderate level. The total British production of 6,300,000 tons in 1930, compared with 10,260,000 tons in 1913, is significant of the position.

In the finished iron section, the demand for crown and the cheaper quality of bars is on an unsatisfactory scale, the present tendency being for the consumption to dwindle rather than expand, although a fair amount of employment is being found for the marked bar mills in the Midlands.

Inactivity in the shipyards, constructional engineering, and locomotive and boiler shops is largely responsible for the relatively slow bulk movement of steel, a slowness which has become accentuated during the past month by the approach of the meeting of the Steel Association. At the moment of writing it is not known whether any concessions —either in the form of price "cuts" or increase of rebates to "all-British" consumers—have been made by producers. The fact remains, however, that some such concession has for long been anticipated by the markets, and it is this factor which has tended to restrict forward commitments, buying of late having been on strictly hand-to-mouth lines. Whether or not lower prices would have the much-desired effect of stimulating the demand for steel is problematical. Steel rollers themselves take the view that it would not. Meanwhile there has been no change in prices.

It is interesting to note that whilst British steel production in 1930 was appreciably smaller than in either of the two previous years, at 7,600,000 tons, it was only slightly below the 1913 output of 7,664,000 tons.

# MARKET PRICES

## ALUMINIUM.

| | | |
|---|---|---|
| 99% Purity | | £85 0 0 |
| Castings, 2.L5 Alloy | lb. | 1/3–1/8 |
| „ 2.L8 „ | „ | 1/4–1/9 |
| „ Silicon „ | „ | — |

## ANTIMONY.

| | |
|---|---|
| English | £36 0 0 |
| Chinese | 25 5 0 |
| Crude | 22 0 0 |

## BRASS.

| | | |
|---|---|---|
| Solid Drawn Tubes | lb. | 10d. |
| Brazed Tubes | lb. | 12d. |
| Rods Drawn | „ | 9⅜d. |
| Wire | „ | 8½d. |
| *Extruded Brass Bars | „ | 5⅛d. |

## COPPER.

| | | |
|---|---|---|
| Standard Cash | | £46 0 0 |
| Electrolytic | | 48 10 0 |
| Best Selected | | 47 0 0 |
| Tough | | 46 10 0 |
| Sheets | | 77 0 0 |
| Wire Bars | | 49 17 6 |
| Ingot Bars | | 49 17 6 |
| Solid Drawn Tubes | lb. | 11¼d. |
| Brazed Tubes | „ | 11¼d. |

## FERRO ALLOYS.

| | | |
|---|---|---|
| ‡Tungsten Metal Powder | lb. | £0 2 6 |
| ‡Ferro Tungsten | „ | 0 2 3 |
| §Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up. | | |
| 2-4% Carbon, scale 11/- per unit | ton | 30 2 6 |
| 4-6% Carbon, scale 7/- per unit | „ | 23 0 0 |
| 6-8% Carbon, scale 7/- per unit | „ | 22 2 6 |
| 8-10% Carbon, scale 7/- per unit | „ | 21 10 0 |
| §Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steel-work. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 10/- per unit | „ | 32 10 0 |
| §Guar. max. 1% Carbon, scale 13/6 per unit | „ | 36 10 0 |
| §Guar. max. 0.7% Carbon, scale 15/- per unit | „ | 40 0 0 |
| ‡Manganese Metal 96-98% Mn. | lb. | 0 1 3 |
| ‡Metallic Chromium | „ | 0 2 7 |
| §Ferro-Vanadium 25-50% | „ | 0 12 8 |
| §Spiegel, 18-20% | ton | 7 5 0 |
| Ferro Silicon— | | |
| Basis 10%, scale 3/- per unit | ton | 5 17 6 |
| 20/30% basis 25%, scale 3/- per unit | „ | 7 15 0 |
| 45/50% basis 45%, scale 5/- per unit | „ | 11 7 6 |
| 70/80% basis 75%, scale 7/- per unit | „ | 18 12 6 |
| 90/95% basis 90%, scale 10/- per unit | „ | 25 6 0 |
| §Silico Manganese 65/75% Mn., basis 65% Mn. | „ | 14 0 0 |
| §Ferro-Carbon Titanium, 15/18% Ti | lb. | 0 0 6 |
| §Ferro Phosphorus, 20-25% | ton | 15 17 6 |

## FUELS.

| | | |
|---|---|---|
| Foundry Coke— | | |
| S. Wales Export | — | — |
| Sheffield Export | £0 15 6 to | £0 16 0 |
| Durham Export | 1 6 0 to | 1 8 0 |
| Furnace Coke— | | |
| Sheffield Export | £0 15 6 to | £0 16 0 |
| S. Wales „ | — | — |
| Durham | 0 14 6 to | 0 15 0 |

## GUN METAL.

| | | |
|---|---|---|
| Commercial Ingots | | £65 0 0 |
| *Gunmetal Bars, Tank brand, 1 in. dia. and upwards | lb. | 0 1 1 |
| *Cored Bars | „ | 0 1 3 |

## LEAD.

| | |
|---|---|
| Soft Foreign | £14 6 3 |
| English | 13 15 0 |

## MANUFACTURED IRON.

| | |
|---|---|
| Scotland— | |
| Crown Bars | £10 5 0 |
| N.E. Coast— | |
| Rivets | 11 10 0 |
| Best Bars | 11 5 0 |
| Common Bars | 10 15 0 |
| Lancashire— | |
| Crown Bars | 10 5 0 |
| Hoops | 13 0 0 |
| Midlands— | |
| Crown Bars | 10 7 6 |
| Marked Bars | 12 10 0 |
| Unmarked Bars | — |
| Nut and Bolt Bars | 9 0 0 |
| Gas Strip | 10 17 6 |
| S. Yorks.— | |
| Best Bars | 11 0 0 |
| Hoops | 12 0 0 |

## PHOSPHOR BRONZE.

| | | |
|---|---|---|
| *Bars, Tank brand, 1 in. dia. and upwards | lb. | 1/1 |
| *Cored Bars | „ | 1/3 |
| †Strip | „ | 1/0½ |
| †Sheet to 10 W.G. | „ | 1/1 |
| †Wire | „ | 1/1¼ |
| †Rods | „ | 1/0½ |
| †Tubes | „ | 1/5¼ |
| †Castings | „ | 1/1 |

†10% Phos. Cop. £30 above B.S.
†15% Phos. Cop. £35 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

## PIG IRON.

| | |
|---|---|
| Scotland— | |
| Hematite M/Nos. | £3 16 0 |
| Foundry No. 1 | 3 19 0 |
| „ No. 3 | 3 16 6 |
| N.E. Coast— | |
| Hematite No. 1 | 3 10 6 |
| Foundry No. 1 | 3 1 0 |
| „ No. 3 | 2 18 6 |
| „ No. 4 | 2 17 6 |
| Cleveland— | |
| Foundry No. 3 | 2 18 6 |
| „ No. 4 | 2 17 6 |
| Silicon Iron | 2 1 0 |
| Forge No. 4 | 2 17 0 |
| N.W. Coast— | |
| Hematite | 4 8 6 |
| Midlands— | |
| N. Staffs Forge No. 4 | 3 6 0 |
| „ Foundry No. 3 | 3 11 0 |
| Northants— | |
| Forge No. 4 | 3 2 6 |
| Foundry No. 3 | 3 7 6 |
| Derbyshire Forge | 3 6 0 |
| „ Foundry No. 3 | 3 11 0 |
| West Coast Hematite | 4 6 6 |
| East „ „ | 4 2 6 |

## SWEDISH CHARCOAL IRON AND STEEL.

| | |
|---|---|
| Pig Iron | £6 0 0 to £7 10 0 |
| Bars, hammered, basis | £17 10 0 „ £18 10 0 |
| Blooms | £10 0 0 „ £12 0 0 |
| Keg steel | £32 0 0 „ £33 0 0 |
| Faggot steel | £20 0 0 „ £24 0 0 |

All per English ton, f.o.b. Gothenburg.

## SCRAP METAL.

| | |
|---|---|
| Copper Clean | £38 0 0 |
| „ Braziery | 35 0 0 |
| „ Wire | — |
| Brass | 28 0 0 |
| Gun Metal | 37 0 0 |
| Zinc | 7 0 0 |
| Aluminium Cuttings | 50 0 0 |
| Lead | 10 10 0 |
| Heavy Steel— | |
| S. Wales | 2 5 0 |
| Scotland | 2 7 6 |
| Cleveland | 2 6 0 |
| Cast Iron— | |
| Lancashire | 2 5 0 |
| S. Wales | 2 7 6 |
| Cleveland | £2 10 0 to 2 12 6 |
| Steel Turnings— | |
| Cleveland | 1 15 0 |
| Lancashire | 1 0 0 |
| Cast Iron Borings— | |
| Cleveland | 1 10 0 |
| Scotland | 1 15 0 |

## SPELTER.

| | |
|---|---|
| G.O.B. Official | — |
| Hard | £10 0 0 |
| English | 13 17 6 |
| India | 11 15 0 |
| Re-melted | 12 0 0 |

## STEEL.

| | |
|---|---|
| Ship, Bridge, and Tank Plates— | |
| Scotland | £8 15 0 |
| North-East Coast | 8 15 0 |
| Midlands | 8 17 6 |
| Boiler Plates (Land), Scotland | 10 0 0 |
| „ „ (Marine) „ | 10 10 0 |
| „ „ (Land), N.E. Coast | 10 0 0 |
| „ „ (Marine) „ | 10 10 0 |
| Angles, Scotland | 8 7 6 |
| „ North-East Coast | 8 7 6 |
| „ Midlands | 8 7 6 |
| Joists | 8 10 0 |
| Heavy Rails | 8 10 0 |
| Fishplates | 12 0 0 |
| Light Rails | 8 17 6 |
| Sheffield— | |
| Siemens Acid Billets | 9 10 0 |
| Hard Basic | 9 12 6 |
| Medium Basic | 8 2 6 |
| Soft Basic | 6 5 0 |
| Hoops | 10 5 0 |
| Manchester— | |
| Hoops | 9 15 0 |
| Scotland, Sheets 20 W.G. | 9 10 0 |

## HIGH SPEED TOOL STEEL.

| | | |
|---|---|---|
| Finished Bars 18% Tungsten | lb. | 3/- |
| Extras | | |
| Round and Squares, ½ in. to ¼ in. | „ | 3d. |
| Under ¼ in. to 3/16 in. | „ | 1/- |
| Round and Squares 3 in. | „ | 4d. |
| Flats under 1 in. × ⅜ in. | „ | 3d. |
| „ „ ½ in. × ¼ in. | „ | 1/- |

## TIN.

| | | |
|---|---|---|
| Standard Cash | | £119 0 0 |
| English | | 120 10 0 |
| Australian | | 120 0 0 |
| Eastern | | 124 5 0 |
| Tin Plates I.C. 20 × 14 | box | 15/6 |
| Block Tin Cash | | £118 10 0 |

## ZINC.

| | |
|---|---|
| English Sheets | £24 0 0 |
| Rods | 26 0 0 |
| Battery Plates | 19 10 0 |

* McKechnie Brothers, Ltd., quoted Jan. 9. † C. Clifford & Son, Ltd., quoted Jan. 9. ‡ Murex Limited, quoted Jan. 9.

Subject to Market fluctuations, Buyers are advised to send inquiries for current prices.

Lancashire Steel Corporation's Current Basis Prices :—Wrought Iron Bars, £10 5s. 0d. ; Mild Steel Bars, £7 6s. 0d. ; Wrought Iron Hoops, £12 ; Best Special Steel Baling Hoops, £8 15s. 0d. ; Soft Steel Hoops (Coopers' and Ordinary Qualities), £8 5s. 0d. to £8 10s. 0d ; C. R. & C. A. Steel Hoops, £12 10s. 0d. to £13 10s. 0d ; "Iris" Bars, £8 15s. 0d. All Nett Cash. Quoted Jan. 3.

§ Prices quoted Dec. 6, ex warehouse.